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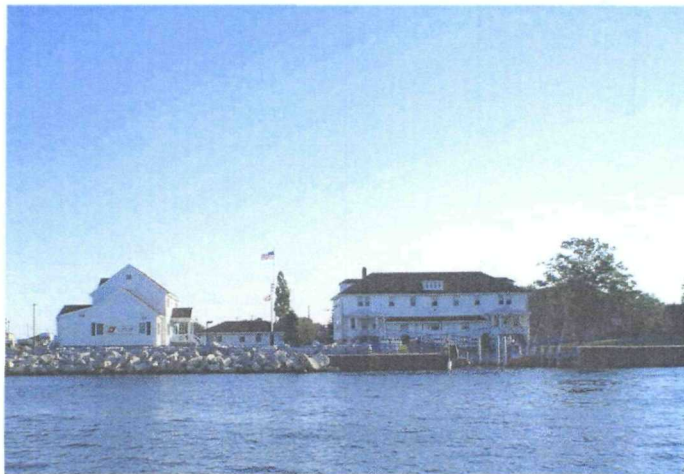
**United States Coast Guard**

## **Field Sampling Plan For Site Evaluation**

**Old Station Ludington  
Ludington, Michigan**

Task Order Number HSCG83-08-J-3CL218  
Master Contract Number HSCG83-08-D-3CL106

August 8, 2008



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Homeland Security

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**Field Sampling Plan  
For Site Evaluation**

Old Station Ludington  
Ludington, Michigan

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DE000122.00001.0002

Date:  
August 8, 2008

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### 1. Introduction

This Field Sampling Plan (FSP) was prepared by ARCADIS on behalf of the U.S. Coast Guard (USCG) for the eastern portion of Old Station Ludington (Site) located in Ludington, Michigan. This FSP is intended to guide Site characterization and removal confirmation activities, if necessary to be consistent with the National Oil and Hazardous Substances Pollution Contingency Plan, 40 CFR Part 300 and to supplement the U.S. Environmental Protection Agency (USEPA) reviewed Quality Assurance Project Plan (QAPP) for the USCG property divestiture program.

Lead impacts are potentially present at concentrations above the 400 milligrams per kilogram (mg/kg) screening level for lead in soil provided in the Revised Interim Soil Lead Guidance for Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Sites and Resource Conservation and Recovery Act (RCRA) Corrective Action Facilities (U.S. Environmental Protection Agency [USEPA] 1994). The lead impacts potentially present in soil are related to historical application and subsequent weathering (i.e., flaking/peeling) of exterior lead-based paint on the old Station Building. The soil analytical results generated during the Site evaluation will be evaluated with respect to naturally occurring background concentrations and applicable or relevant and appropriate requirements (ARARs) to determine if lead concentrations in soil at the Site pose a risk to potential receptors.

Groundwater will be evaluated at the Site to determine if soil impacts potentially present could have resulted in groundwater impacts. Groundwater samples will be collected for analysis of total and dissolved lead. The analytical results will be evaluated with respect to naturally occurring background concentrations and ARARs to determine if dissolved-phase lead concentrations at the Site pose a risk to potential groundwater and surface water receptors. The solubility and toxicity of lead in water are affected by pH and hardness of the water. Therefore these parameters will be included as part of the evaluation of groundwater and surface water adjacent to the site, to which groundwater vents.

The screening levels referenced in this document are only intended to help guide the characterization and delineation of potential impacts to soil and groundwater, if present. If necessary based on Site evaluation results, the USCG will identify and evaluate ARARs, to be considered (TBC) guidance, and select removal action objectives (RAOs) as part of an Engineering Evaluation/Cost Analysis (EE/CA) for the Site.

The federal government intends on transferring the eastern portion of Old Station Ludington property to the City of Ludington, where the property will then be used for public purposes (e.g., park or museum). Based on the intended future uses of the

property, the Site evaluation data objectives will focus on determining whether historical usage of lead based paints on the old Station Building has impacted the soil and potentially impacted groundwater. If soil and/or groundwater impacts are identified, they will be delineated laterally and vertically. Waste characterization samples will be collected to determine the appropriate means of disposal.

This FSP is intended to be used in conjunction with other supporting documents including the USEPA reviewed QAPP (ARCADIS, 2008). The objective of this FSP is to develop an approach that will characterize the nature and extent of the contamination, if present. This will include demonstrating that impacts potentially present have been adequately delineated horizontally and vertically to generate accurate surface area and volume estimates of impacted soil. Area and volume estimates will be used to evaluate cleanup approach and feasibility. This evaluation will be performed and documented in the EE/CA for the Site, and a soil Removal Action Work Plan (RAWP) will be prepared, if warranted, based on results of the Site evaluation and intended future land use and ownership.

### 1.1 Document Organization

This FSP describes the project setting and Site history, and presents the sampling objectives and anticipated project schedule. It also provides procedures for:

- Establishing soil sampling locations
- Establishing monitoring well locations
- Monitoring well construction, development and sampling
- Field screening
- Sample collection for laboratory analyses
- Quality assurance and quality control
- Sample handling and management
- Waste management
- Documentation

Field work will be conducted in accordance with the Site-specific Health and Safety Plan (HASP) provided in Appendix A. Standard Operating Procedures (SOPs) for Site evaluation activities are provided in Appendix B. Example field reports including soil boring logs, monitoring well construction logs, and groundwater sampling logs are included in Appendix C. The specification sheet and levels of detection for the Niton XL3t X-Ray fluorescence (XRF) analyzer for field screening is included in Appendix D.

### 1.2 Project Setting

The Old Station Ludington was reportedly constructed in 1892 at Ludington, Michigan (see Figure 1 and Figure 2). The Site currently consists of the old Station Building, a garage/engineering building, the new Station Building, and a boat slip along the Pere Marquette River. The portion of the Site to be transferred to the City of Ludington includes the old Station Building and landscaped area to the east of the old Station Building (see Figure 2). According to the Final Phase I Environmental Site Assessment, USCG Station Ludington, Michigan (URS Group Inc., February 2001) the Station building and garage were built in 1892 and included offices, a galley, a mess deck and berthing rooms. The Engineering Building was built to the west of the Site between 1972 and 1981.

#### 1.2.1 Archeological Survey

In accordance with the National Historic Preservation Act (NHPA) an archeological survey was performed prior to initiating Site evaluation and potential removal action work at the Site. The Site archeological survey was performed by Commonwealth Cultural Resources (CCR) on July 10, 2008. The final report on the archeological survey is expected by August 1, 2008 and will be submitted to the State Historic Preservation Officer (SHPO) once received. Based on historical knowledge of the Site and conversations with CCR, it is not anticipated that the archeological survey will result in any potential conflicts with the proposed activities. Therefore a statement of "no historic properties affected" is anticipated from the SHPO.

#### 1.2.2 Threatened or Endangered Species Assessment

An Endangered Species Assessment was not completed for the Site, due to the physical setting of the portion of the property to be transferred to the City of Ludington, which consists mainly of the old Station Building, paved sidewalks, and limited landscaped areas. Based on the developed nature of the property, the USCG has concluded that suitable habitat for threatened or endangered species does not exist at the property.

### 1.2.3 Environmental Site Assessments

A Phase I Environmental Site Assessment was conducted by URS Group Inc. (URS) on the Site and on the parcel of land to the west of the Site that is also owned by the USCG. The results are presented in a report dated February 20, 2001. The report identified two possible underground storage tanks (USTs) on the land to the west of the Site owned by USCG. The USTs are scheduled to be further investigated during 2008 separately from the lead investigation. A second Phase I Environmental Assessment (focusing on the portion of the property to be transferred to the City of Ludington) was prepared by Otwell Mawby, P.C. for the City of Ludington dated April 30, 2007. The Phase I identified a former waste oil UST adjacent to the old Station Building, as well as the possibility of impacts related to a floor drain where boats had been kept at the old Station Building, and the potential for asbestos and lead-based paint based on the age of the buildings.

### 1.3 FSP Objective

The primary objectives of this FSP are as follows.

- Provide procedures for field sample collection to characterize Site soils and groundwater, including the nature and extent of lead impacts in soil, and the potential for soil impacts to have affected Site groundwater, in accordance with the Code of Federal Regulations (CFR) 40 CFR 300.410 Removal Site Evaluation.
- Describe and justify any variances to the procedures described in this document or to accepted practices.

### 1.4 Project Schedule

The USCG has established an anticipated project completion goal of the second quarter of 2009 to prepare the eastern portion of the property for divestiture to the City of Ludington. In response to a request from the City of Ludington to expedite the Site evaluation, the USCG intends to proceed with the field work described herein during August 2008. The USCG will submit preliminary data from the Site evaluation to the City of Ludington by September 2008, and submit a summary report of results to the City of Ludington by September 2008. If soil and/or groundwater impacts are identified during the Site evaluation, the USCG will prepare an EE/CA, followed by preparation of a RAWP if warranted, during the fourth quarter 2008.

## 2. Site Evaluation Soil Sampling

Lead impacts in soil are potentially present as a result of flaking/peeling of lead-based exterior building paint. Therefore, Site evaluation samples will be collected using a combination of biased (initial screening and lateral and vertical delineation samples) and unbiased (random) sampling strategies as described in the following sections. Procedures for soil sample collection are summarized in Sections 4.1 and 4.2 and defined in the SOP provided in Appendix B. Procedures and methods for laboratory analysis are defined in the QAPP (ARCADIS, 2008).

### 2.1 Biased Soil Sample Locations

Biased Site evaluation sampling will incorporate a multi-phase approach combining initial evaluation samples and lateral and vertical delineation samples as described in the following sections 2.1.1 and 2.1.2.

Data reporting and validation levels referenced in the following sections are defined in the QAPP Worksheet 14 (ARCADIS, 2008).

#### 2.1.1 Initial Evaluation Soil Samples

Soil samples will be collected from the surface soils (0 to 6 inches below ground surface) in areas adjacent to the old Station Building where lead impacts from flaking/peeling paint are likely to be encountered, and these samples will be field screened using the XRF analyzer (see Figure 3). Field screening with the XRF analyzer will be performed in accordance with USEPA Method 6200 (provided in Appendix B).

The initial row of samples will be collected at approximately 1 to 2 feet from the exterior building walls, at a minimum average spacing of approximately 1 sample per 25 linear feet (minimum 1 sample per exterior wall segment). If visible evidence of potential soil impact is observed (i.e., paint chips on soil surface adjacent to buildings or areas of building walls where exterior paint appears more weathered than others), these areas will be targeted during the sampling. Initial evaluation samples will not be collected within the paved areas.

Approximately 25 percent of the initial surface soil evaluation samples adjacent to the old Station Building will be collected and submitted for laboratory analysis of lead in accordance with procedures and methods indicated in Section 5 and defined in the Site-specific QAPP (ARCADIS, 2008).

The reporting for the initial evaluation sample results will include a Level 2 data package and validation in accordance with the Site-specific QAPP. The data will be used to quantify the range of lead concentrations present in soil and to assess the correlation between the XRF field screening results and laboratory analytical results. If XRF field screening results are all below 100 mg/kg a level 3 data package will be requested from the laboratory for all initial evaluation samples.

#### 2.1.2 Delineation Soil Samples

##### 2.1.2.1 Vertical Delineation Soil Samples

If potential impacts are identified in surface soils (0 to 6 inches) (i.e., XRF measurements greater than 100 mg/kg) during field screening, samples will be collected from subsequent depths at the same location (1 to 2 feet, 2 to 3 feet below ground surface) and screened using the XRF for vertical delineation. If potential impacts are identified in 1 to 2 foot samples by field screening, samples will be collected at the same location from 2 to 3 feet below ground surface. All vertical delineation samples (1 to 2 feet, and 2 to 3 feet if needed) will be collected and submitted for laboratory analysis of lead in accordance with procedures and methods indicated in Section 5 and the Site-specific QAPP. Field screening with the XRF analyzer will be performed in accordance with USEPA Method 6200 (provided in Appendix B).

The reporting for the vertical delineation sample results will include a Level 2 data package and validation in accordance with the Site-specific QAPP. The data will be used to define the vertical extent of soil impacts, if present, and to estimate the depth of soil removal areas if warranted. If XRF field screening results are all below 100 mg/kg a level 3 data package will be requested from the laboratory for all delineation samples collected.

##### 2.1.2.2 Lateral Delineation Soil Samples

Additional step-out samples will be collected and field screened using the XRF analyzer to determine the lateral extent of lead impacts from the exterior building surfaces (See Figure 3). Step-out samples will be collected approximately 5 feet from the initial samples at the same depth and within the same soil horizon as the initial samples. Step-out sampling will continue at approximately 5 foot intervals until results of the XRF field screening are less than 100 mg/kg, or until structures are encountered limiting further step-out sampling. The outermost step-out samples from Site structures will be collected and submitted for laboratory analysis of lead in accordance with procedures and methods indicated in Section 5 and the Site-specific QAPP. Field

screening with the XRF analyzer will be performed in accordance with USEPA Method 6200 (provided in Appendix B).

The reporting for the lateral delineation sample results will include a Level 2 data package and validation in accordance with the Site-specific QAPP. The data will be used to define the lateral extent of soil impacts, if present, and to estimate the extent of soil removal areas, if warranted. If XRF field screening results are all below 100 mg/kg a level 3 data package will be requested from the laboratory for all delineation samples collected.

## 2.2 Unbiased Soil Sample Locations

Systematic random grid sampling will be performed to evaluate soils on the eastern portion of the property where no current structures are present and where no visual evidence of potential impacts is observed. Specifically the grassy areas to the east and south of the old Station Building will be targeted for systematic random sampling. This evaluation will be performed to identify potential impacts from previous structures that are no longer present, or from other potential sources (e.g., relocated soil). Samples will not be collected within the paved areas.

A random sampling grid was established based on the size of the area to be sampled and calculated according to the following relationship:

$$GI = \sqrt{A\pi / L}$$

Where:

GI = Grid interval (feet);

A = Area to be evaluated (square feet); and

L = Length of area to be evaluated (feet).

A grid system based on the 12 foot interval determined in the above equation was overlaid on the area of the Site to be evaluated by systematic random sampling (see Figure 3). Each of the grid cells was assigned a number 1 to n (where n is the total number of grid cells for the area being evaluated). A random number-generating function was used to randomly select 20 percent of the grid cells for sampling. Based on the area to be sampled (approximately 6,750 square feet) approximately 10 random grid sample locations will be sampled. More samples may be collected if warranted based on field observation.

Random grid samples will be collected from the same depth intervals targeted during the biased sampling at each location, field screened using the XRF analyzer and submitted for laboratory lead analysis. If XRF field screening results indicate potential impacts (i.e., results greater than 100 mg/kg), additional vertical and step-out samples will be collected, field screened, and submitted for laboratory analysis as described above to define the extent of the potential impacts. Field screening with the XRF analyzer will be performed in accordance with USEPA Method 6200 (provided in Appendix B). If XRF field screening results are all below 100 mg/kg a level 3 data package will be requested from the laboratory for all systematic random samples collected.

A 95 percent upper confidence level (UCL) for the arithmetic mean concentration of lead in soil will be calculated for the unbiased sample data set in accordance with USEPA guidance (USEPA 1992). The 95 percent UCL will be evaluated with respect to the screening level and background concentrations, as appropriate, to determine if additional areas of potential impact are present at the Site.

### **2.3 Background Soil Sample Locations**

#### **2.3.1 Background Soil Type Characterization**

Approximately 3 soil borings will be performed to characterize the soil types present at the Site. This analysis is aimed at identifying the depositional origin of soils and determining if multiple soil horizons are present that should be considered during Site evaluation sampling and removal action if warranted. Soil type characterization borings will be performed at locations which will be determined onsite during field activities. It is possible that fewer than 3 soil borings will be performed due to the limited size of the Site and uncertainty of current conditions. At a minimum two background samples will be collected.

Soils will be continuously collected and logged from the ground surface until the water table is encountered. Information about soil type, color, physical properties, and depositional environment will be recorded to characterize soils and to identify distinct strata if present. This information will be used to aid in the overall Site evaluation to determine discrete depth intervals for background sample collection and to identify targeted screen intervals for monitoring well installation. Soil borings will be backfilled with hydrated bentonite pellets.



### 2.3.2 Background Soil Lead Concentration

Background samples will be collected to evaluate the concentration of naturally occurring lead in soils in the vicinity of the Site with respect to on-site concentrations.

Background sample locations will be selected at locations which will be determined onsite during field activities. It is possible that fewer than 3 soil borings will be performed due to the limited size of the Site and uncertainty of current conditions. Sample locations which are believed to be upwind of known Site structures with respect to the prevailing wind direction, contain soils of similar composition and depositional origin to those throughout the Site, and are in an area believed to be unimpacted by Site operations or other potential sources will be chosen. Potential background soil sample locations are shown on Figure 3. If field screening results indicate potential soil impacts at any of the proposed background sample locations, additional properties will be evaluated as potential background sample locations.

Background samples will be collected from depth intervals (0 to 0.5 feet, 1 to 2 feet, etc.) comparable to samples collected during the biased and unbiased Site evaluation sampling described above.

## 3. Site Evaluation Groundwater Sampling

Groundwater samples will be collected to determine if soil impacts potentially present as a result of flaking/peeling of lead-based exterior building paint could have potentially impacted Site groundwater. Groundwater monitoring wells will be installed to collect groundwater samples for comparison to a Site-specific screening level as defined during the pending ARARs evaluation and to background concentrations of lead.

### 3.1 Monitoring Well Locations

The locations of groundwater wells at the Site will be positioned as follows:

- One well installed in an upgradient location near the property boundary, in an area believed to be unimpacted. This well will be installed to collect a background groundwater sample to evaluate the concentration of lead naturally occurring in local groundwater. The background well will be set within the shallow unconsolidated hydrogeologic unit at a similar depth interval as the other monitoring wells on-Site.
- Two wells installed hydraulically downgradient, and outside of the area of known or potential soil impacts. These wells will be placed to identify any impacts in

groundwater potentially related to Site soil lead impacts. The wells will be installed outside of the potentially impacted areas to prevent dragdown or cross-contamination issues.

Monitoring wells at the Site will be installed in the first unconsolidated water bearing hydrogeologic unit encountered in the subsurface. Potential locations for the monitoring wells are shown on Figure 3. Final locations will be based on field observations and XRF field screening results. Field procedures for the installation, development and sampling of groundwater monitoring wells are described in Section 4.

### **3.2 Groundwater Samples**

Groundwater samples will be collected from each of the monitoring wells installed on-Site using low-flow purging and sampling techniques. Samples will be submitted for laboratory analysis of total and dissolved lead according to USEPA Method 7420 and hardness according to SM 2340B. Procedures for groundwater sample collection are summarized in Section 4.5 and detailed in the SOP provided in Appendix B. All groundwater samples will be submitted for Level 3 data reporting and validation as defined in the QAPP (ARCADIS, 2008).

## **4. Field Procedures**

### **4.1 X-Ray Fluorescence Field Screening**

Field screening of soil samples will be conducted using a Niton XL3t portable XRF analyzer in accordance with USEPA Method 6200 for ex-situ field screening for lead using XRF (USEPA 2007) provided in Appendix B.

In this procedure, the portion of soil selected for field screening is prepared by placing a volume of soil into a disposable plastic re-sealable bag. Any large pieces of soil within the plastic bag are broken into smaller pieces, and the soil is blended to form as homogeneous a mixture as is practical. Each sample will be screened by placing the XRF analyzer onto the sample for 30 seconds to obtain comparable results among the samples. XRF analyzer results will be recorded in instrument units that are equivalent to parts per million.

Quality control measures described in the attached USEPA Method 6200 will be employed to provide the highest quality data possible from the XRF analyzer. In addition to these measures, duplicate samples will be collected for all XRF field screening samples at a rate of 1 per 10 samples to assess and document the variability (i.e., measurement error) of the instrument.

A copy of the Niton XL3t Specification Sheet and Levels of Detection are included in Appendix D.

#### 4.2 Soil Sample Collection

Due to the presumed source of potential soil impacts (i.e., paint chips in near-surface soils) and presumed proximity of impacts, if present adjacent to the old Station Building, soil sample collection will be performed using hand tools (e.g., hand auger, shovel, scoop, etc.). Other sampling methods such as direct-push equipment will be evaluated as needed.

Soil samples collected for laboratory analysis will be collected using a decontaminated stainless steel or disposable plastic scoop to fill the appropriate containers. The SOP for soil sample collection is provided in Appendix B.

Soil samples, with the exception of waste characterization samples, will be collected as discrete or "grab" samples. The sampling procedure will meet USEPA sampling requirements using properly decontaminated or disposable sampling equipment. Reusable equipment will be decontaminated in accordance with procedures described in Section 4.6 prior to each use.

Soil samples will be representative of the overall soil matrix at each sample location and will be generally free of organic material and gravel unless that material represents the primary soil type at the particular sample location. Portions of samples intended for XRF field screening will be placed in plastic bags and labeled to await field screening as described in Section 4.1. Portions of samples intended for laboratory analysis will be placed in the appropriate laboratory-supplied containers, labeled, and stored on ice as described in Section 7 to await shipment to the laboratory.

#### 4.3 Monitoring Well Installation

A hollow stem auger rig equipped with 4 1/4-inch hollow stem augers will be utilized for installing monitoring wells. Soils will be continuously logged and classified at each location to confirm the lithology identified during the background soil type characterization described in Section 2.3.1. The observations collected during installation will be used to determine the monitoring well screen interval placement and ensure wells are screened within the appropriate hydrogeologic unit.

#### 4.4 Monitoring Well Construction and Development

Monitoring wells will be constructed of 2-inch, Schedule 40 polyvinyl chloride (PVC) casings and 5-foot-long, 0.01-inch slot stainless-steel wire-wrapped screens. The annulus surrounding the screen will be backfilled using an appropriately sized sand pack for the slot size and surrounding hydrogeologic unit to 2 feet above the top of the well screen. The remainder of the borehole annulus will be backfilled with bentonite chips to 2 feet below surface. Monitoring wells will be completed with a sealable locking cap and a flush-mount manhole type cover set into a concrete pad. Well construction details will be recorded on a Monitoring Well Construction Log and maintained in the project file.

Well development will be performed using a surge-block and vacuum pump or decontaminated submersible pump to remove fines and reestablish hydrologic communication with the surrounding hydrogeologic unit. Proper development of monitoring wells is critical to obtaining high-quality representative groundwater samples. The pump intake will be moved up and down throughout the 5-foot screen interval to ensure development of the entire screen interval. A field turbidity meter will be used to determine turbidity during development. Wells will be developed until a turbidity of 10 nephelometric turbidity units (NTU) is achieved, with a minimum of 10 casing volumes purged from each well. Visual observations of the purge water, along with field turbidity measurements and the volume of water purged from the well, will be recorded in the field log book or on well development logs.

#### 4.5 Groundwater Sample Collection

All groundwater samples collected for laboratory analysis will be collected using a peristaltic pump under low-flow purging and sampling conditions as described in the Low-Flow Groundwater Sampling SOP provided in Appendix B. Groundwater sampling will be performed after sufficient time has passed since well development to allow for artificially suspended soil particles to settle out of suspension (i.e., at least 3 days).

All groundwater samples will be collected as discrete or "grab" samples. Dedicated tubing constructed of polyethylene (or other inert material) will be used for each well. Groundwater purging will be performed by lowering the tubing to the midpoint of the well screen. Groundwater will be purged at a rate that minimizes drawdown in the well, not to exceed 500 milliliters per minute. A YSI Model 556 or similar instrument will be used with a flow-through cell to measure and record water quality field parameters including pH, temperature, specific conductance, dissolved oxygen, oxygen reduction potential. A separate instrument will be used to measure turbidity.

Groundwater samples will be collected in the appropriate laboratory-supplied pre-preserved containers once field parameters have stabilized (typically 2 to 3 consecutive readings within 10%) and 2 to 3 consecutive turbidity measurements below 10 NTUs. Specifically the stabilization criteria will be as follows.

<u>Parameter</u>	<u>Stabilization Criteria</u>
pH	$\pm 0.1$ units
Specific Conductance	$\pm 3\%$ S/cm
Oxidation Reduction Potential	$\pm 10$ mV
Turbidity	2-3 readings < 10 NTU
Dissolved Oxygen	$\pm 0.3$ mg/L

Samples collected for total lead analysis will be field preserved at the time of sample collection. Samples collected for dissolved lead analysis will be field-filtered using an appropriately sized filter (i.e., 0.45 micron) to allow naturally suspended colloidal particles to pass, and preserved immediately following filtration. The water quality field parameters will be recorded in the field log book or on groundwater sampling logs. Groundwater samples will be placed in the appropriate laboratory-supplied containers, preserved, labeled, and stored on ice to await shipment to the laboratory.

#### 4.6 Equipment Decontamination and Investigation-Derived Waste Management

All reusable equipment will be decontaminated in accordance with the SOP for Decontamination provided in Appendix B. Reusable sampling equipment will be decontaminated prior to the first use and in between each sampling location.

All loose soil will be removed from soil sampling equipment. The sampling equipment will then be placed in a bucket with a detergent and distilled water solution and scrubbed to remove any residual soil. Sampling equipment will then be rinsed in a bucket of distilled water. Finally, the sampling equipment will be removed from the rinse water and given a final rinse of distilled water from a spray bottle. Both the detergent wash and clean water rinse solutions will be periodically changed as needed.

All investigation-derived waste (IDW) including soil, spent decontamination fluids, well development water and purge water will be placed in labeled 55-gallon drums. Well development water and purge water will be containerized with the decontamination water. The drums will be securely sealed, labeled, and will remain at the Site pending receipt of laboratory results. All drums will be removed from the Site and properly

disposed of within 30 days of completion of the Site evaluation and/or removal action activities.

### 4.7 Site Survey

All sample locations, monitoring wells and relevant Site-specific features will be recorded using Global Positioning System (GPS) or traditional survey techniques in accordance with the SOP for Site Survey attached in Appendix B. The existing USCG base map and coordinate system for the Site will be utilized, and all soil sample locations and removal area extents will be surveyed and tied into existing Site benchmarks for accuracy. The survey data will be used to update the existing USCG Site maps. The top of casing elevation for each monitoring well will be surveyed to an accuracy of 0.01 feet.

### 5. Analysis

All soil evaluation will be submitted to Test America Laboratories in Watertown, Wisconsin (Test America), for analysis of fine and coarse fraction lead by USEPA Method 7420 as defined in the QAPP. The fine fraction is defined as the portion of sample that passes through a 250-micron (60 mesh) sieve. The coarse fraction is defined as the portion of sample retained by the 250-micron sieve. The total lead concentration in soil is expressed as follows:

$$TotalLead = [(A + Wf) + (B + Wc)] / (Wf + Wc)$$

Where:

$A$  = Lead concentration (mg/kg dry) in fine fraction;  
 $B$  = Lead concentration (mg/kg dry) in coarse fraction;  
 $Wf$  = Total weight of fine fraction; and  
 $Wc$  = Total weight of coarse fraction.

All groundwater samples will be submitted to Test America for analysis of total and dissolved lead by USEPA Method 7420 and hardness by SM 2340B.

Soil waste characterization samples will be submitted to Test America for analysis of total lead and toxicity characteristic leaching procedure (TCLP) lead, pH, ignitability and paint filter test. Waste water characterization samples will be submitted to Test America for analysis of total lead, TCLP lead, pH and ignitability.

The laboratory sample preparation, extraction, and analytical methods for each of these analyses are summarized in QAPP Worksheet 20 (ARCADIS, 2008).

### 6. Quality Assurance/Quality Control

Quality Assurance/Quality Control (QA/QC) procedures, including field and analytical procedures, equipment calibration, chain-of-custody requirements, sample containers and preservatives, and QA/QC sample types and frequency, are defined in the Site-specific QAPP (ARCADIS, 2008).

Analytical results for Site evaluation soil samples (including lateral and vertical delineation samples if needed) will include Level 2 data reporting and validation. If XRF field screening indicates soil samples are below 100 mg/kg, Level 3 data reporting and validation will be requested. Analytical results for removal confirmation samples (if warranted) will include Level 3 data reporting and validation. All groundwater samples will be submitted for Level 3 data reporting and validation. The data reporting and validation levels are defined in the QAPP Worksheet 14 (ARCADIS 2008).

### 7. Sample Handling and Management

All samples will be handled according to the chain-of-custody protocol described in the QAPP Worksheet 27 (ARCADIS 2008).

#### 7.1 Sample Information

Following sample collection, the portion of the samples to be field screened will be placed in re-sealable plastic bags and labeled with the sample identification information, including location and sample depth, to await XRF analysis.

Samples being shipped for laboratory analysis will be labeled with the sample identification information, date of sample collection, and requested analysis. Samples will be placed in a cooler on ice to await shipment to the laboratory.

#### 7.2 Sample Designation System

Samples collected at the Site will be identified according to the following USCG sample identification system:

##### 7.2.1 Soil and Groundwater Samples

SLSB##xxxx-Event

Where:

XX = Facility ID, solid waste management unit (SWMU) number, or two-digit Site abbreviation (e.g., **SL** for Station Ludington)

SB = Sample station type (e.g., **SB** for soil boring, **SS** for surface soil, **MW** for Monitoring Well, **RC** for removal confirmation)

## = Sample location (e.g., **04** for the fourth soil boring, or fourth surface sample)

xxxx = Sample number (e.g., **0001** for the first sample collected vertically within a soil boring, **0002** for the second)

Event = investigation phase or sampling event description (e.g., AUG2008 Site Eval.)

An example sample identification would be SLSB040002-AUG2008 Site Eval for the second soil sample collected from the fourth soil boring at the Station Ludington Site during the August 2008 Site evaluation.

### 7.2.2 QA/QC Samples

All QA/QC samples will be identified according to the system described above and numbered sequentially (e.g., **XXDUP01**xxxx-AUG2008 Site Eval for the first duplicate sample, **XXEB02**xxxx-AUG2008 Site Eval for the second equipment blank).

### 7.3 Sample Packaging and Shipping Requirements

Samples shipped to the laboratory via overnight courier will be packed inside a cooler, with bubble wrap and ice, in a manner to prevent breakage of sample containers. Sample containers will be securely sealed to prevent damage or loss of the sample. Additional detail regarding sample packaging and shipping requirements is provided in QAPP Worksheet 27 (ARCADIS 2008).

The Chain-of-Custody form will be completed by the sampler and sealed inside the cooler during shipment. Custody seals will be placed on the outside of the cooler. Sample coolers will be properly labeled and shipped according to U.S. Department of Transportation requirements.



## 8. Waste Management

Based on results of the soil waste composite samples, soils generated during the Site evaluation will be disposed of at an appropriately licensed landfill. Soils exhibiting less than 5 mg/L lead (the toxicity characteristic of the hazardous waste criterion) in the TCLP leachate will be managed as non-hazardous soil waste. Soils exhibiting greater than 5 mg/L lead in the leachate will be considered characteristically hazardous and disposed of at an appropriately licensed landfill.

Groundwater collected during purging and sampling of the monitoring wells will be containerized with the well development and decontamination water. Based on results of the IDW water composite sample, the containerized IDW water will be transported and disposed of at an appropriately licensed facility.

If either waste characterization sample is outside of the acceptable pH range or fails ignitability or paint filter test (soils only) the waste will be properly labeled, transported and disposed of according to applicable State and Federal requirements.

All disposable personal protective equipment and sampling supplies will be disposed of as general refuse in on-site dumpsters. Any PPE or disposable sampling equipment used in the sampling or handling of characteristically hazardous soils or groundwater will be placed in drums with the characteristically hazardous soil and disposed of accordingly with the hazardous soil waste.

## 9. Documentation

All Site activities will be recorded in a Site-specific field notebook or on Field Report Logs. Included in the documentation will be procedures used for sampling and other activities, weather conditions, personnel working on the Site, and a chronological log of Site activities. Copies of the Chain-of-Custody form, Field Report logs, Soil Boring Logs, Well Construction Logs, Groundwater Sampling Logs and Equipment Calibration logs are provided in Appendix C.

## 10. References

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USEPA. 2007. *Field Portable X-Ray Fluorescence Spectrometry for the Determination of Elemental Concentrations in Soil and Sediment, SW-846, Method 6200.* February 2007.

## FIGURES





UNITED STATES COAST GUARD  
LUDINGTON STATION  
LUDINGTON, MICHIGAN

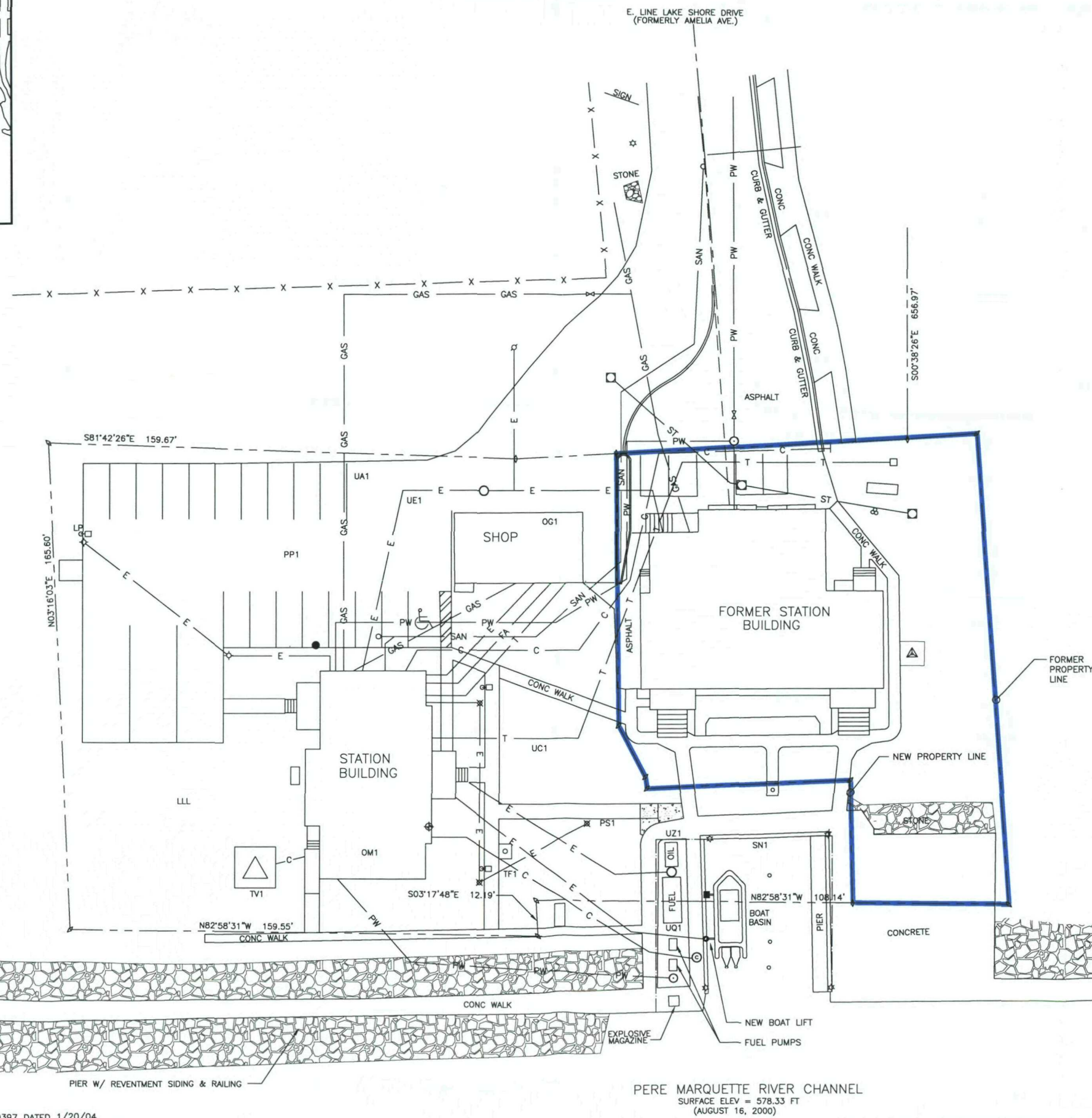
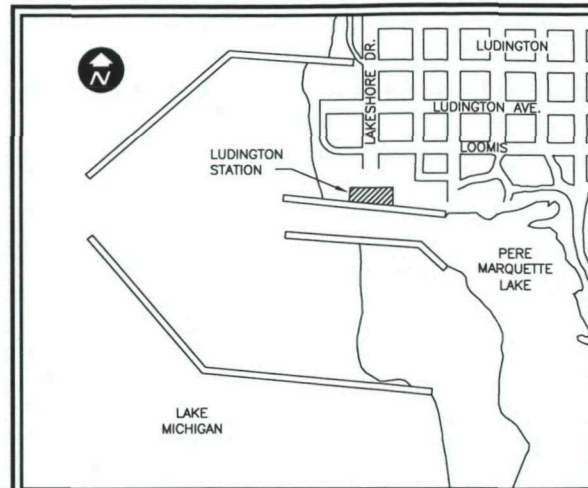
### SITE LOCATION MAP



FIGURE

1





0 40 80  
SCALE IN FEET


## SITE LAYOUT



FIGURE  
2

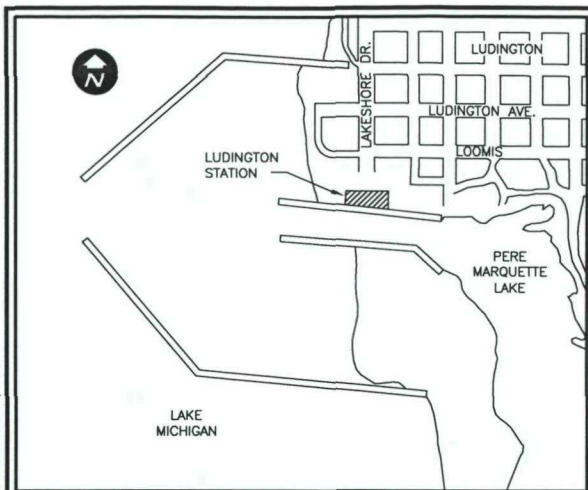
REAL PROPERTY FACILITY NAME	
RPFN	FACILITY NAME
LLL	LAND
OC1	GARAGE
OM1	STATION BUILDING
PS1	SIDEWALKS
PP1	PARKING AREA
SN1	SSP BULKHEAD
TF1	FLAG POLE
TV1	RADIO TOWER FM 45'
UA1	GAS LINES
UC1	TELEPHONE SYSTEM
UE1	ELECTRICAL SYSTEM
UQ1	1500 GAL. F/O & 500 GAL. GAS CONVAULT
US1	SANITARY SEWER
US2	STORM SEWER
UW1	WATER
UZ1	250 GAL. W/O TANK (AG)

## LEGEND

■	CATCH BASIN	—C—	COMM LINES
◇	CONCRETE MONUMENT	—E—	ELECTRICAL
≡	GREASE TRAP	—GAS—	GAS
⬆	IRON PIPE	—SAN—	SANITARY SEWER
⬆	IRON ROD	—ST—	STORM SEWER
⬆	LIGHT POLE	—T—	TELEPHONE
●	MANHOLE—SANITARY SEWER	—GAS/DSL—	GAS & DIESEL D.W. PIPE
□	MANHOLE—STORM SEWER	—X—	FENCE
≡	ELECTRICAL OUTLET	— - -	PROPERTY LINE
⊠	GAS METER	—PW—	POTABLE WATER
⚡	POWER POLE	—AF—	FIRE ALARM
■	PULL BOX		
●	SHORE TIE/LIGHT		
⋈	VALVE		
			PORTION OF PROPERTY TO BE TRANSFERRED TO CITY OF LUDINGTON (AREA OF INVESTIGATION)

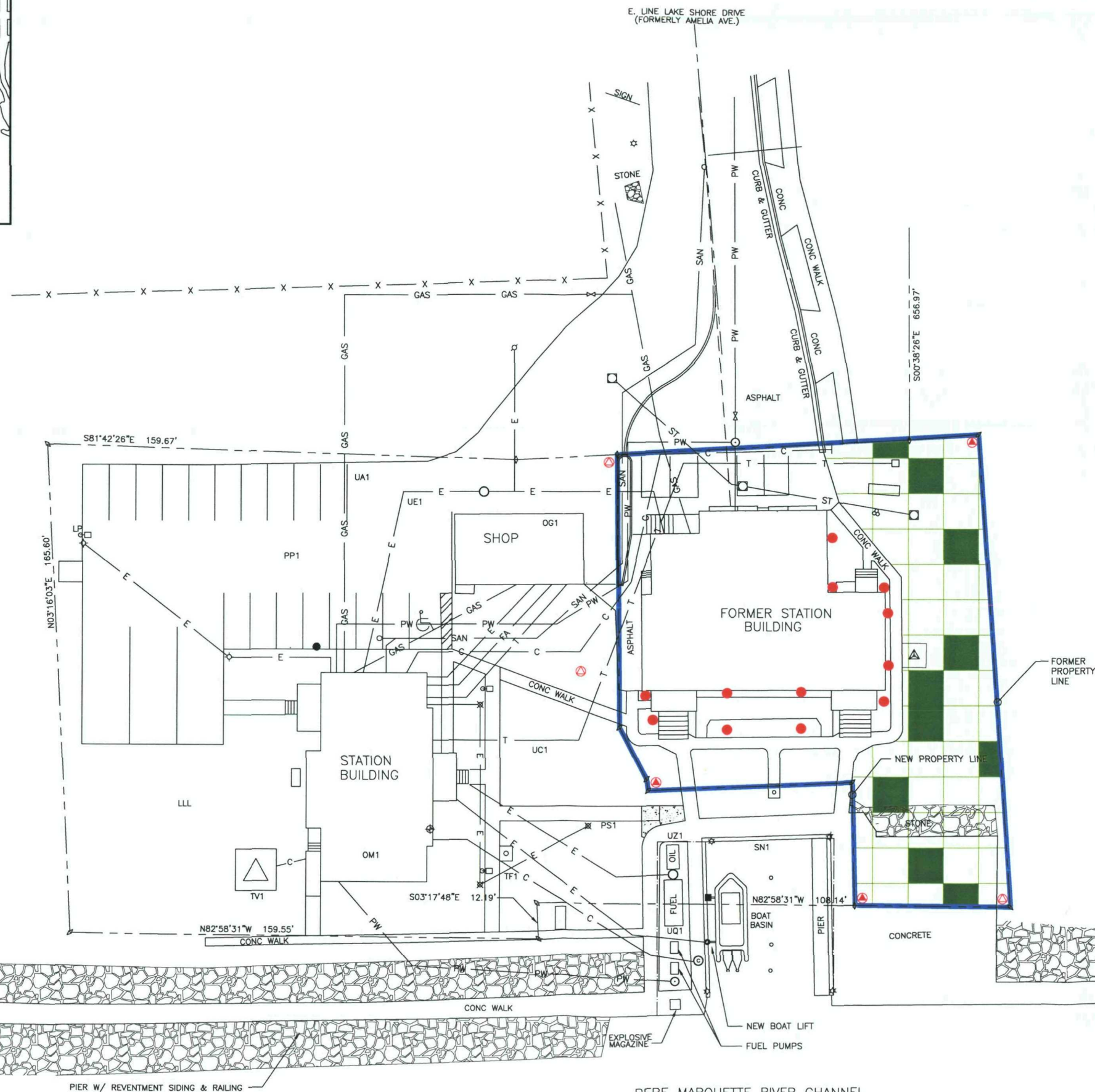


CITY: NOVI DIV: GROUP: ENV DB: PIC: PM: TM: TR: PROJECT NUMBER: G:\GIS\Project Files\USCG\USCG Great Lakes\Ludington\CAD\_Datal09-30397.dwg LAYOUT: PROPOSED SAMPLING LOCATION. SAVED: 7/31/2008 12:08 PM PLOTSTYLETABLE: ARCADIS.NOV.CTB PLOTTED: 7/31/2008 12:50 PM BY: YARBROUGH, TOBI



VICINITY MAP

STATUTE MILE  
0 1/4 1/2



REAL PROPERTY FACILITY NAME

RPFN	FACILITY NAME
LLL	LAND
OG1	GARAGE
OM1	STATION BUILDING
PS1	SIDEWALKS
PP1	PARKING AREA
SN1	SSP BULKHEAD
TF1	FLAG POLE
TV1	RADIO TOWER FM 45'
UA1	GAS LINES
UC1	TELEPHONE SYSTEM
UE1	ELECTRICAL SYSTEM
UQ1	1500 GAL. F/O & 500 GAL. GAS CONVAULT
US1	SANITARY SEWER
US2	STORM SEWER
UW1	WATER
UZ1	250 GAL. W/O TANK (AG)

LEGEND

■ CATCH BASIN	—C— COMM LINES
◇ CONCRETE MONUMENT	—E— ELECTRICAL
■ GREASE TRAP	—GAS— GAS
◇ IRON PIPE	—SAN— SANITARY SEWER
◇ IRON ROD	—ST— STORM SEWER
◇ LIGHT POLE	—T— TELEPHONE
● MANHOLE-SANITARY SEWER	—GAS/DSL— GAS & DIESEL D.W. PIPE
□ MANHOLE-STORM SEWER	—X— FENCE
■ ELECTRICAL OUTLET	—PW— POTABLE WATER
■ GAS METER	—AF— FIRE ALARM
◇ POWER POLE	
■ PULL BOX	
● SHORE TIE/LIGHT	
■ VALVE	
● PROPOSED INITIAL BIASED SOIL SAMPLE LOCATION	
● PROPOSED BACKGROUND SOIL SAMPLE AND MONITORING WELL LOCATION	
● ALTERNATE MONITORING WELL LOCATION	
	■ PORTION OF PROPERTY TO BE TRANSFERRED TO CITY OF LUDINGTON (AREA OF INVESTIGATION)
	■ PROPOSED RANDOM SOIL SAMPLING GRID
	■ RANDOMLY SELECTED CELL FOR SAMPLING

NOTE: LATERAL AND VERTICAL STEP-OUT SOIL SAMPLES WILL BE COLLECTED IF NEEDED BASED ON RESULTS OF THE INITIAL SAMPLES



0 40 80  
SCALE IN FEET

UNITED STATES COAST GUARD  
STATION LUDINGTON  
LUDINGTON, MICHIGAN

PROPOSED SAMPLING LOCATIONS



FIGURE  
3

## Appendix A

Health and Safety Plan

## **Health and Safety Plan**

Client Name: United States Coast  
Guard Civil Engineering Unit Cleveland

Project Name: United States Coast  
Guard Old Station Ludington

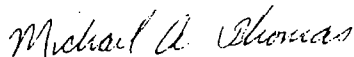
Date: July 2008



ARCADIS



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Gregory E. Zellmer, PG  
Senior Geologist

### Health and Safety Plan

United States Coast Guard Old  
Station Ludington

Prepared for:  
United States Coast Guard Civil  
Engineering Unit Cleveland

Prepared by:  
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Our Ref.:  
DE000122.0001

Date:  
July 16, 2008

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### Appendices

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D	Real Time Air Monitoring Log
E	Map to the Hospital
F	Job Safety Analysis
G	Material Safety Data Sheets
H	Utility Locate Policy and Procedure
I	Lead Policy and Procedure

**1. Introduction**

All work on this project will be carried out in compliance with ARCADIS' Health and Safety Manual and the Occupational Safety and Health Administration's Hazardous Waste Operations and Emergency Response regulation 29 CFR 1910.120. Specific safety information for the project is contained in this Health and Safety Plan (HASP). All personnel working on hazardous operations or in the area of hazardous operations shall read and be familiar with this HASP before doing any work. All project personnel shall sign the certification page acknowledging that they have read and understand this HASP.

Changes in the scope of the project or introduction of new hazards to the project shall require revision of the HASP by the HASP writer and reviewer, and approval by the Project Manager. The HASP Addendum Form is included as Appendix A. Addendums are to be added to every copy of the HASP, and logged in the following table to verify that all copies of the HASP are current:

Addendum Number	Date of Addendum	Reason for Addendum	Person Completing Addendum
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

## 2. Project Description

### 2.1 Project Dates

Projected Start Date: 9/8/08

Projected End Date: Open

### 2.2 Site Background

The Site is located at 101 South Lakeshore, Ludington, Michigan, in a residential area of the City of Ludington, Mason County. To the north of the Site is City of Ludington property used for park space and a boat launch, and South Lakeshore Drive ends at the Site. To the northeast of the Site is a multi-family apartment/condo development. To the east of the Site is the Starboard Tack Condominium complex. To the south of the Site is the current boat storage well used by the United States Coast Guard, and The Pere Marquette Lake channel which flows west into Lake Michigan. To the west of the Site is the new operating United States Coast Guard Station and a small storage garage.

The Site is currently occupied by the former United States Coast Guard station building. The building is currently vacant and being used for miscellaneous storage. The ground floor of the building was being used as a garage for miscellaneous storage. The garage was formerly used for the storage of boats and has a sloped floor which allowed for the drainage of water from the boats which were winched into the building on a rail system from the boat well to the south of the building. There is no evidence of the former rail system for the storage of the boats and the doors on the south side of the building were all removed and closed in. The remaining portions of the ground floor of the building were used for storage of equipment, an exercise room, and boiler room.

The main floor of the building was used for office, kitchen, and dining room. The second floor of the building was used for bedrooms, restrooms and storage space. The third floor/attic appeared to have been used for the storage of staff personal items.

### 2.3 List of Project Tasks and Scope of Work

**Task 1 – Archaeological Survey.** Prior to any drilling or earth moving activities at the Site, an archaeological survey will need to be conducted at the Site. ARCADIS will

retain a subcontractor to conduct a Phase 1 Archaeological Survey in accordance with the Section 106 of the National Historical Preservation Act of 1996 (16 U.S. Code 470) and in compliance with 36 CFR 800.4 "Identification of Historic Properties". The survey will consist of the following tasks:

- Conduct background research of the Site.
- Complete shovel test pits to approximately 1.5 feet to 2 feet below ground surface.
- Screen and inspect soil for artifacts
- Prepare a technical report for submittal to the State Historical Preservation Office (SHPO) for review and comment.

The survey will be conducted prior to the Site Investigation and supplemented if necessary prior to any potential removal actions. The survey activities at the site will be conducted in level D personal protective equipment. ARCADIS will provide oversight during the survey activities, which are anticipated to take two days to complete.

**Task 2 – Lead in Soil Investigation.** Lead impacts to soil are potentially present as a result of flaking/peeling of lead based exterior building paint. The investigation to evaluate the lateral and vertical extent of lead in soil will consist of collecting soil samples using a biased sampling strategy.

Surface soil samples will be collected at approximately 1 to 2 feet from the exterior building walls, at an average spacing of approximately 1 sample per 25 linear feet. No soil samples will be collected from beneath concrete or asphaltic surfaces. Based on the layout of the grounds and the size of the former station building, ARCADIS estimates that initially nine locations will be sampled. The final location and number of samples will be determined in the field based on observations of the soil surrounding the building and the condition of the building.

Soil samples will be collected from the surface soils (0-6 inches below ground surface) in areas adjacent to the former station building at the Site where lead impacts from flaking/peeling paint are likely to be encountered. These samples will be field screened using an XRF Analyzer. If the field-screening results indicate the potential for impacts, ARCADIS will collect subsurface soil samples from subsequent depth intervals at the same location and screen the samples using XRF for vertical delineation. Once the

field screening indicates lead impacts below the target screening concentration specified in the FSP, vertical delineation samples will be collected and submitted for laboratory analysis. ARCADIS estimates that a maximum of five subsurface soil samples will be collected and submitted for laboratory analysis.

Additional step-out samples will be collected and field screened using the XRF analyzer to determine the lateral extent of lead impacts from the exterior building surfaces. Step-out samples will be collected approximately 5 feet from the initial samples and will continue at approximately 5 foot intervals until results of the XRF field screening are less than 100 mg/kg. The outermost step-out samples from Site structures will be collected and submitted for laboratory analysis.

Three background soil samples will be collected from depth intervals comparable to samples collected during the biased Site evaluation sampling described above. The sample locations will be selected with respect to the prevailing wind direction, contain soils of similar composition and depositional origin to those throughout the Site, and are in a area believed not to be impacted by Site operations or other potential sources.

**Task 3 – Monitoring Well Installation/Groundwater Sampling.** To evaluate the potential for lead to leach from the lead-based exterior paint, ARCADIS will install a maximum of three 2-inch diameter groundwater monitoring wells and collect groundwater samples for laboratory analysis. Following installation, the wells will be developed and sampled using low-flow purge and sampling techniques in accordance with the QAPP and FSP. The samples will be collected from each well on a quarterly basis for one year (four sample events).

**Task 4 – Geophysical Survey.** ARCADIS understands that the status of the two USTs associated with the site (a diesel and used oil USTs) is unknown. One of the USTs was reportedly removed; however, there is no documentation of the removal activities or fuel piping abandonment, or if impacts were observed during the removal. Based on this information and the lack of documentation regarding the status of the other UST and fuel piping, ARCADIS will conduct a geophysical survey of the two areas where the USTs reportedly existed to determine if they are still in place. If the USTs are in place, ARCADIS will provide USCG with recommendations for removal and assessment in accordance with the MDEQ-PRD Part 201 guidance for conducting site assessments.

**Task 5 – UST Impact Delineation.** If the results of the geophysical survey indicated that the USTs and associated piping have been removed or are not present, ARCADIS

will complete a maximum of 12 soil borings to 15 feet below ground surface to characterize potential impacts to soil in the vicinity of the former USTs and former fuel piping. The final number and location of soil borings will be determined based on geophysical survey results and field observations.

ARCADIS will complete three of the soil borings as 2-inch diameter monitoring wells to characterize potential groundwater impacts, if field screening results indicate a petroleum hydrocarbon release is evident. Following installation, the wells will be developed and sampled using low-flow purge sampling techniques in accordance with the MDEQ-RRD Operational Memorandum 2. Groundwater samples will be collected from each monitoring well on a quarterly basis for one year (four sample events).

**Task 6 – Investigation-Derived Waste (IDW) Management.** At a minimum, ARCADIS anticipates generating soil cuttings, personal protective equipment (PPE) and decontamination and purge fluids during implementation of the field investigation. ALL IDW will be placed in steel Department of Transportation (DOT) approved 55-gallon drums and will be stored temporarily on the Site at location to be determined by USCG. All IDW drums will be properly labeled and dated to indicate the contents and origin of the materials. ARCADIS will coordinate soil and liquid waste characterization, manifesting, transportation, and off-site disposal within 60 days of the completion of the investigation activities.

## 2.4 Site Description

### Site Type: (Check as many as applicable)

<input type="checkbox"/>	Active	<input type="checkbox"/>	Secure	<input checked="" type="checkbox"/>	Industrial	<input type="checkbox"/>	Landfill	<input type="checkbox"/>	Service station
<input checked="" type="checkbox"/>	Inactive	<input checked="" type="checkbox"/>	Unsecured	<input type="checkbox"/>	Commercial	<input type="checkbox"/>	Well field	<input type="checkbox"/>	Water work
<input type="checkbox"/>		<input type="checkbox"/>	Uncontrolled	<input type="checkbox"/>	Residential	<input type="checkbox"/>	Railroad	<input type="checkbox"/>	Undeveloped
<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	Other specify:				

### Surrounding Population:

<input checked="" type="checkbox"/>	Residential	<input checked="" type="checkbox"/>	Industrial	<input type="checkbox"/>	Commercial	<input type="checkbox"/>	Rural	<input type="checkbox"/>	Other:
-------------------------------------	-------------	-------------------------------------	------------	--------------------------	------------	--------------------------	-------	--------------------------	--------

Approximately 25 percent of the site is grass covered, with a wooded area encompassing the northwestern, northeastern, and southeastern sides of the site.



### 3. Hazard/Risk Analysis and Communication

#### 3.1 Hazard Assessment and Risk Control (HARC)

Each hazard is evaluated and rated for the level of risk based on the task of the project. A thorough analysis of hazards and their risk is completed using the following HARC matrix:

Risk Assessment Matrix		Likelihood Ratings**				
Consequences Ratings*		A	B	C	D	E
People	Property	Never heard of in the world	Heard of incident in industry	Incident has occurred in ARCADIS Group	Happens several times a year in ARCADIS OpCo	Happens several times a year at ARCADIS Worksite
0 - No health effect	0 - No damage	Low	Low	Low	Low	Low
1 - Slight health effect	1 - Slight damage	Low	Low	Low	Low	Low
2 - Minor health effect	2 - Minor damage	Low	Low	Low	Medium	Medium
3 - Major health effect	3 - Local damage	Low	Low	Medium	Medium	
4 - PTD or 1 fatality	4 - Major damage	Low	Medium	Medium		
5 - Multiple fatalities	5 - Extensive damage	Medium	Medium			

	HAZARD	RISK LEVEL	HAZARD	RISK LEVEL
Physical Hazards  <input type="checkbox"/> None	<input checked="" type="checkbox"/> Heat	Low	<input checked="" type="checkbox"/> Holes/Pits	Low
	<input checked="" type="checkbox"/> Cold	Low	<input type="checkbox"/> Ionizing radiation	
	<input checked="" type="checkbox"/> Noise	Low	<input type="checkbox"/> Non-ionizing radiation	
	<input checked="" type="checkbox"/> Walking/Working Surfaces	Low	<input type="checkbox"/> Electricity	
	<input checked="" type="checkbox"/> Visible Dust	Medium	<input checked="" type="checkbox"/> Severe Weather	Low
	<input type="checkbox"/> LASER		<input checked="" type="checkbox"/> Poor lighting	Low
	<input type="checkbox"/> Other:		<input checked="" type="checkbox"/> Overhead Hazards	Medium
	<input type="checkbox"/> Other:		<input type="checkbox"/> Other:	

Environmental/Equipment Hazards  <input type="checkbox"/> None	<input checked="" type="checkbox"/> Heavy machinery	High	<input type="checkbox"/> Cranes/Hoists/Rigging	
	<input checked="" type="checkbox"/> Trenching/excavation	Medium	<input type="checkbox"/> Ladders	
	<input type="checkbox"/> Docks – marine operations		<input type="checkbox"/> Scaffolding	
	<input type="checkbox"/> Docks – loading		<input type="checkbox"/> Man lifts	
	<input type="checkbox"/> Diving operations		<input type="checkbox"/> Welding	
	<input type="checkbox"/> Drilling		<input type="checkbox"/> Gas cylinders	
	<input type="checkbox"/> Forklifts		<input type="checkbox"/> Roadway work	
	<input checked="" type="checkbox"/> Water operations work	Low	<input type="checkbox"/> Railroad work	
	<input type="checkbox"/> Elevated heights		<input type="checkbox"/> Energized equipment (LO/TO)	
	<input checked="" type="checkbox"/> Overhead/Underground utilities	Medium	<input type="checkbox"/> Pressurized equipment	
<input type="checkbox"/> Confined spaces		<input type="checkbox"/> Drums and containers		
<input checked="" type="checkbox"/> Power Tools/Hand Tools	Low	<input type="checkbox"/> Other:		
Biological Hazards  <input type="checkbox"/> None	<input type="checkbox"/> Animal/human fluids or blood		<input type="checkbox"/> Contaminated needles	
	<input type="checkbox"/> Animal/human tissue(s)		<input type="checkbox"/> Live bacterial cultures	
	<input checked="" type="checkbox"/> Poisonous/irritating plants	Low	<input checked="" type="checkbox"/> Insects/rodents/snakes	Low
	<input type="checkbox"/> Other:		<input type="checkbox"/> Other:	
Ergonomic Hazards  <input type="checkbox"/> None	<input checked="" type="checkbox"/> Repetitive motion	Low	<input type="checkbox"/> Limited movement	
	<input checked="" type="checkbox"/> Awkward position	Low	<input type="checkbox"/> Forceful exertions	
	<input type="checkbox"/> Heavy lifting		<input checked="" type="checkbox"/> Vibration	Low
	<input type="checkbox"/> Frequent lifting		<input type="checkbox"/> Other:	
	<input type="checkbox"/> Other:		<input type="checkbox"/> Other:	
Personal Safety/Security  <input type="checkbox"/> None	<input type="checkbox"/> Personal safety		<input checked="" type="checkbox"/> Employees working early/late	Low
	<input type="checkbox"/> Security issue		<input type="checkbox"/> Potentially dangerous wildlife	
	<input checked="" type="checkbox"/> Project site in isolated area	Low	<input type="checkbox"/> Guard or stray dogs in area	
	<input checked="" type="checkbox"/> Employees working alone	Low	<input type="checkbox"/> No/limited cell phone service	
	<input type="checkbox"/> Other:		<input type="checkbox"/> Other:	
Driving Safety  <input type="checkbox"/> None	<input checked="" type="checkbox"/> Driving early/late	Low	<input type="checkbox"/> City Driving	
	<input type="checkbox"/> Driving long trip		<input type="checkbox"/> Pulling trailer	
	<input type="checkbox"/> Driving Off-road		<input type="checkbox"/> Other:	
	<input type="checkbox"/> Other:			

### 3.2 Job Safety Analysis

A Job Safety Analysis (JSA) must be completed for the task(s) being completed. Hazards identified above will be addressed in the JSA as well as control methods to be used to protect employees and property from hazards. JSAs for this project are included as **Appendix F**.

## 3.3 Chemical Hazards

Chemical	Hazards	TLV/PEL* 8-hr TWA	Ionization Potential	Estimate of quantity to be used or stored on site	Symptoms of Overexposure	Special Precautions
Lead	Noncombustible Solid	0.050 mg/m <sup>3</sup>	NA	NA	Lassitude, insomnia; facial pallor; anorexia, low-weight, malnutrition; constipation, abdominal pain, colic, anemia; gingival lead line; tremor; paralysis of the wrist and ankles; encephalopathy; kidney disease; irritated eyes; hypotension	Lead is not only an inhalation hazard from airborne lead- containing dust, but also a significant ingestion hazard if proper personal hygiene and decontamination do not take place.
Petroleum Hydrocarbons	Flammable Liquid	350 mg/m <sup>3</sup>	NA	NA	Irritation to the eyes, nose and throat; dizziness, drowsiness, headache, nausea; dry cracked skin; chemical pneumonitis (aspiration liquid)	A mixture of paraffin's that may contain a small amount of aromatic hydrocarbons.

\*The TLV (Threshold Limit Value) from the American Conference of Governmental Industrial Hygienists is listed unless the PEL (Permissible Exposure Limit), designated by OSHA, is lower.

## 3.4 Hazard Communication (HazCom)

Prior to conducting the investigative activities, ARCADIS, USCG, and the subcontractor will conduct a tail gate safety meeting. ARCADIS, USCG, or the drilling

subcontractor personnel will not sample or handle any potential lead-based paint from the structures.

ARCADIS personnel and its subcontractors will not use or store any chemicals during the site activities. The USCG has vacated the site; thus, there are no chemicals stored at the site.

A copy of a Material Safety Data Sheets (MSDS) for lead is attached in Appendix G. In addition, the underground piping associated with the former underground storage tanks may contain residual heating oil (No. 2 fuel oil). Therefore, a copy of a MSDS for No. 2 fuel oil is included in Appendix G.

### 3.5 Air Monitoring

Air monitoring will be performed for each task per the table below. The abatement contractor will be responsible for conducting and documenting Real Time Air Monitoring during the lead-based paint abatement.

<b>TASK 1 – Archaeological Survey</b>		
Is air monitoring required for this task? <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO		
<b>Monitoring Equipment</b>	<b>Monitoring Frequency</b>	<b>Action Level</b>
<b>TASK 2 – Lead in Soil Investigation</b>		
Is air monitoring required for this task? <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO		
<b>Monitoring Equipment</b>	<b>Monitoring Frequency</b>	<b>Action Level</b>

<b>TASK 3 – Monitoring Well Installation/Groundwater Sampling</b>		
Is air monitoring required for this task? <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO		
<b>Monitoring Equipment</b>	<b>Monitoring Frequency</b>	<b>Action Level</b>
<b>TASK 4 – Geological Survey</b>		
Is air monitoring required for this task? <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO		
<b>Monitoring Equipment</b>	<b>Monitoring Frequency</b>	<b>Action Level</b>
<b>TASK 5 – UST Impact Delineation</b>		
Is air monitoring required for this task? <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO		
<b>Monitoring Equipment</b>	<b>Monitoring Frequency</b>	<b>Action Level</b>
<b>TASK 6 – Investigation-Derived Waste (IDW) Management</b>		
Is air monitoring required for this task? <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO		
<b>Monitoring Equipment</b>	<b>Monitoring Frequency</b>	<b>Action Level</b>

### 3.6 Client-Specific Health and Safety Requirements

Project workers will comply with the client's safety requirements at all times. The Project Manager is to be notified immediately if subcontractors or visitors are not following client-specific safety guidelines.

#### 4. Decontamination Procedures

Level D decontamination protocol will be used with the following decontamination stations:

Level C Decontamination Steps		Level D Decontamination Steps	
1	Equipment Drop	1	Equipment Drop
2	Outer Garment, Boots, and Glove Wash and Rinse	2	Glove and Boot Wash and Rinse
3	Disposable Garment, Boots, and Glove Removal	3	Disposable Garment, Outer Boot, and Glove Removal
4	Cartridge Change (if necessary)	4	Field Wash
5	Remove Respiratory Protection		
6	Field Wash		

Place an X by all decontamination equipment that is required at the Site.

Decontamination Equipment Checklist			
x	Scrub Brushes	x	Garbage Bags
x	Waste Containers	x	Paper Towels
x	Soap	x	Isopropyl Alcohol
x	Plastic Tubs	x	Pump Spray Bottles
x	Plastic Drop Cloths	x	Pump Spray Bottles (water)

#### 5. Emergency Procedures

In the event that an injury, over-exposure or spill has occurred, emergency response procedures will be implemented. The Site Safety Officer (SSO) will coordinate the entry and exit of response personnel during an emergency and make emergency contacts as necessary from the following list. After immediate notifications are made, the SSO will contact the Project Manager.

### 5.1 Emergency Contact Information

Emergency Contact	Phone Numbers
Local Police	911
Local Ambulance	911
Local Fire Department	911
Local Hospital – Mem. Med. Ctr. Of West Michigan	231.843.2591
National Response Center (all spills in reportable quantities)	800.424.8802
U.S. Coast Guard (spills to water)	804.441.3516
Associate Project Manager – Greg Zellmer	248.994.2283 (O) 248.789.8319 (C)
Client Contact – Greg Carpenter	216-902-6219 (O)
WORK CARE	800.455.6155

The Project Manager will make the following notifications:

Name	Phone Numbers
Environmental Division H&S Director – Mike Thomas	720.344.3835 (O) 720.308.2147 (C)
Health & Safety Manager/Specialist – Pat Vollertsen	720.344.3779 (O) 303.518.0622 (C)
Regional Health & Safety Manager – Lauren Edwards	317.231.6500 (O) 317.657.7234 (C)
Office Health & Safety Representative – Greg Zellmer	248.994.2283 (O) 248.789.8319 (C)

If emergency attention is not needed but professional medical attention is necessary, the employee will be taken to:

Medical Facility: Memorial Medical Center of West Michigan  
Address: One Atkinson Drive  
Ludington, MI 49431-1999  
Phone Number: 231.843.2591

A map to the medical facility is included in **Appendix E**.

### 5.2 Emergency Equipment

	Emergency shower	x	First-aid kit
x	Emergency eyewash	x	Cell phone/radio
x	Fire extinguisher		Chemical spill kit
	Other:		Other:

All employees working on this project will be shown the location and proper use of all emergency equipment prior to beginning work on the project.

## **6. Department of Transportation (DOT) Dangerous Good Shipping Requirements**

Hazardous materials and dangerous goods (re: Canadian regulatory term) are those materials that have one or more of the following characteristics: explosives, compressed and liquefied gases, flammable liquids and solids, oxidizing materials, and other substances that are poisonous, infectious, radioactive or corrosive. It is the handling, loading, packing or placing of hazardous materials (dangerous goods) in or from a container or vehicle at any facility for the purpose of transportation (including storing) in the course of transportation. This also includes the packing and transporting for air and ground shipment of laboratory analysis samples.

Regulations governing hazardous materials and dangerous goods exist to protect people, the environment, or property when these goods are being transported by road, rail, sea, or air. Given the increased emphasis of federal (i.e., Federal Aviation Administration and US Department of Transportation, and the Transportation of Dangerous Goods Act) attention to the transport of hazard material-containing goods, it is imperative that all shipments are packaged and transported such that they adhere to all federal requirements. ARCADIS has strict policies in place, whether shipping via ground or air, designed to meet the associated federal requirements. As such, only ARCADIS staff that have been trained in the proper methods to prepare and ship hazardous materials are authorized to do so. If you have not received training on the appropriate preparation and shipping protocols, you are to contact your supervisor or health and safety representative prior to packaging and/or shipping any material that is, or suspected to be, hazardous.

## **7. Project Team and Training**

### **7.1 Personnel List**

The associate project manager is responsible for safety at the project site and for ensuring that all site workers have reviewed the HASP and understand the hazards. The associate project manager must also ensure that the necessary PPE is procured and provided to site workers. The task manager assists the associate project manager in implementing safety measures at the site, and conveys any safety concerns to the associate project manager.

The SSO officer is responsible for implementing the HASP at the project site. If any site personnel or visitors do not comply with the HASP, the SSO will cease all work



until personnel/visitors comply. The SSO will contact the APM/TM to inform them of any personnel not complying with the HASP.

Associate Project Manager: Greg Zellmer  
Task Manager: Troy Sclafani  
Site Safety Officer: Jim Rinke  
Site Workers: Jim Rinke, John Rogers, James Kralik

### 7.2 Training Requirements

All personnel working at the site must have the necessary training based on the hazards present. The following training is required for all site workers:

<b>Training Required:</b>  <input type="checkbox"/> None	<input checked="" type="checkbox"/> 40-hour HAZWOPER <input checked="" type="checkbox"/> 24-hour HAZWOPER <input checked="" type="checkbox"/> HAZWOPER site supervisor <input checked="" type="checkbox"/> OSHA 30-hour Construction <input checked="" type="checkbox"/> OSHA 10-hour Construction <input checked="" type="checkbox"/> PPE <input checked="" type="checkbox"/> Respiratory protection <input checked="" type="checkbox"/> Chemical hygiene <input checked="" type="checkbox"/> Hazard communication <input checked="" type="checkbox"/> Hazardous waste <input checked="" type="checkbox"/> First-aid/CPR/Bloodborne pathogens <input checked="" type="checkbox"/> DOT/IATA hazmat transportation <input type="checkbox"/> Diving <input type="checkbox"/> Boating safety	<input type="checkbox"/> Confined space <input type="checkbox"/> Lockout/tagout <input type="checkbox"/> Electricity <input checked="" type="checkbox"/> Fire extinguishers <input type="checkbox"/> Fall protection <input type="checkbox"/> Noise exposure <input type="checkbox"/> Forklifts <input type="checkbox"/> Asbestos <input checked="" type="checkbox"/> Lead <input type="checkbox"/> Cadmium <input type="checkbox"/> Radiation safety <input type="checkbox"/> Client specific <input type="checkbox"/> Other
<b>Medical Screening</b>	<input checked="" type="checkbox"/> Medical Surveillance Exam (HAZWOPER) <input type="checkbox"/> Client required drug and/or alcohol testing	<input type="checkbox"/> Blood and/or urine screening for other hazardous substances

All 40-hour HAZWOPER trained personnel who are working at HAZWOPER project sites are required to participate in the ARCADIS medical surveillance program as outlined in the Corporate Health and Safety Manual.

### 7.3 Subcontractors

A copy of this HASP is to be provided to all subcontractors prior to the start of work so that the subcontractor is informed of the hazards at the site. While the ARCADIS HASP will be the minimum H&S requirements for the work completed by ARCADIS

and its subcontractors, each subcontractor, in coordination with ARCADIS H&S personnel, is expected to perform its operations in accordance with its own HASP, policies and procedures unique to the subcontractor's work to ensure that hazards associated with the performance of the work activities are properly controlled. Copies of any required safety documentation for a subcontractor's work activities will be provided to ARCADIS for review prior to the start of on-site activities.

In the event that the subcontractor's procedures/requirements conflict with requirements specified in this HASP, the more stringent guidance will be adopted after discussion and agreement between the subcontractor and ARCADIS project H&S personnel. Hazards not listed in this HASP, but known to the subcontractor or known to be associated with the subcontractor's services, must be identified and addressed to the ARCADIS Project or Task Manager and SSO prior to beginning work operations.

## 8. Project Personnel HASP Certification

## 8.1 ARCADIS Personnel Signature Page

I certify that I have read, understand, and will abide by the safety requirements outlined in this HASP.

[illegible]

## 8.2 Subcontractor Acknowledgement: Receipt of HASP

ARCADIS claims no responsibility for the use of this HASP by others although subcontractors working at the Site may use this HASP as a guidance document. In any event, ARCADIS does not guarantee the health and/or safety of any person entering this Site. Strict adherence to the health and safety guidelines provided herein will reduce, but not eliminate, the potential for injury at this Site. To this end, health and safety becomes the inherent responsibility of personnel working at the Site.

[illegible]

8.3 Visitor Acknowledgement and Acceptance of HASP

By signing below, I waive, release and discharge the Owner of the Site and ARCADIS and their employees from any future claims for bodily and personal injuries which may result from my presence at, entering, or leaving the Site and in any way arising from or related to any and all known and unknown conditions on the Site.

Name	Company	Reason for Visit	Date/Time On Site	Date/Time Off Site

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**Appendix A**

HASP Addendum Pages

# ARCADIS

## Addendum Page

This form should be used to document any changes required to this HASP. These changes may be a result of changes to the scope of services, changes in field conditions, new hazards identified on the Site, higher or lower hazards than anticipated, etc. Please complete this form prior to the next work day once the changes have been identified. Review the modifications with all Site staff, including subcontractors, during the daily tailgate briefing, and complete the tailgate briefing form as required. Attach a copy of the addendum to all copies of the HASP including the Site copy, and log in the Addendum Log in Section 1.0.

Addendum Number: \_\_\_\_\_ Project Number: \_\_\_\_\_  
Date of Changed Conditions: \_\_\_\_\_ Date of Addendum: \_\_\_\_\_

### Description of Change that Results in Modifications to HASP:

### Hazard Analysis for Change in Work:

HAZARD		Level of Risk:	
Source of Hazard			
Admin. & Eng. Controls		PPE:	
HAZARD		Level of Risk:	
Source of Hazard			
Admin. & Eng. Controls		PPE:	

Signed: \_\_\_\_\_  
Project Manager

Signed: \_\_\_\_\_  
Site Safety Officer

Signed: \_\_\_\_\_  
H&S Plan Writer

Signed: \_\_\_\_\_  
H&S Plan Reviewer

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**Appendix B**

PPE Checklist



Description (Specify Material or Type in Box)	Level Of Protection R = Required O = Optional	
	D	C
<b>Body</b>		
Coveralls	R (Tyvek)	
Chemical Protective Suit		
Splash Apron		
Rain Suit	O	
Traffic Safety Vest (reflective)	R	
<b>Head</b>		
Hard Hat (if does not create other hazard)	R	
Head Warmer (depends on temperature and weather)	O	
<b>Eyes &amp; Face</b>		
Safety Glasses (incorporate sun protection as necessary)	R	
Goggles (based on hazard)	O	
Splash Guard (based on hazard)		
<b>Ears</b>		
Ear Plugs	R	
Ear Muffs	O	
<b>Hands and Arms</b>		
Outer Chemical Resistant Gloves	O	
Inner Chemical Resistant Gloves (i.e. Nitrile)	R	
Insulated Gloves	O	
Work Gloves	O	
<b>Foot</b>		
Safety Boots (steel toe and shank)	R	
Rubber, Chemical Resistant Boots		
Rubber Boots	R (near water)	
Disposable Boot Covers	R	
<b>Respiratory Protection (indicate cartridge type where applicable)</b>		
Dust Protection		
1/2 Mask APR		
Full Face APR		
Full Face Canister APR with HEPA cartridges		R
Powered APR		
<b>Other Supplies</b>		
First Aid Kit	R	
Fire Extinguisher	R	
Mobile Phone	R	
Traffic Cones	O	
Walkie Talkies	O	
Water or Other Fluid Replenishment	R	
Eye Wash Station	O	
Eye Wash Bottle	R	
Wash and Dry Towelettes	R	
Sunscreen (SPF 15 or higher)	R	
Insect Repellant	R	

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**Appendix C**  
Tailgate Briefing Sign-in Log



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**Appendix D**

Real Time Air Monitoring Log

Real Time Air Monitoring Data Collection Form

Document all air monitoring conducted on the Site below based on Section E of the HASP. Keep this form with the project files.

Site Name: \_\_\_\_\_ Date: \_\_\_\_\_

Instrument: \_\_\_\_\_ Model: \_\_\_\_\_ Serial #: \_\_\_\_\_

Calibration Method: (material used, settings, etc.)	
Calibration Results:	
Calibrated By:	

Activity Being Monitored	Compounds Monitored	Time	Reading	Action Required? Y/N

Describe Any Actions Taken as a Result of this Air Monitoring and Why:

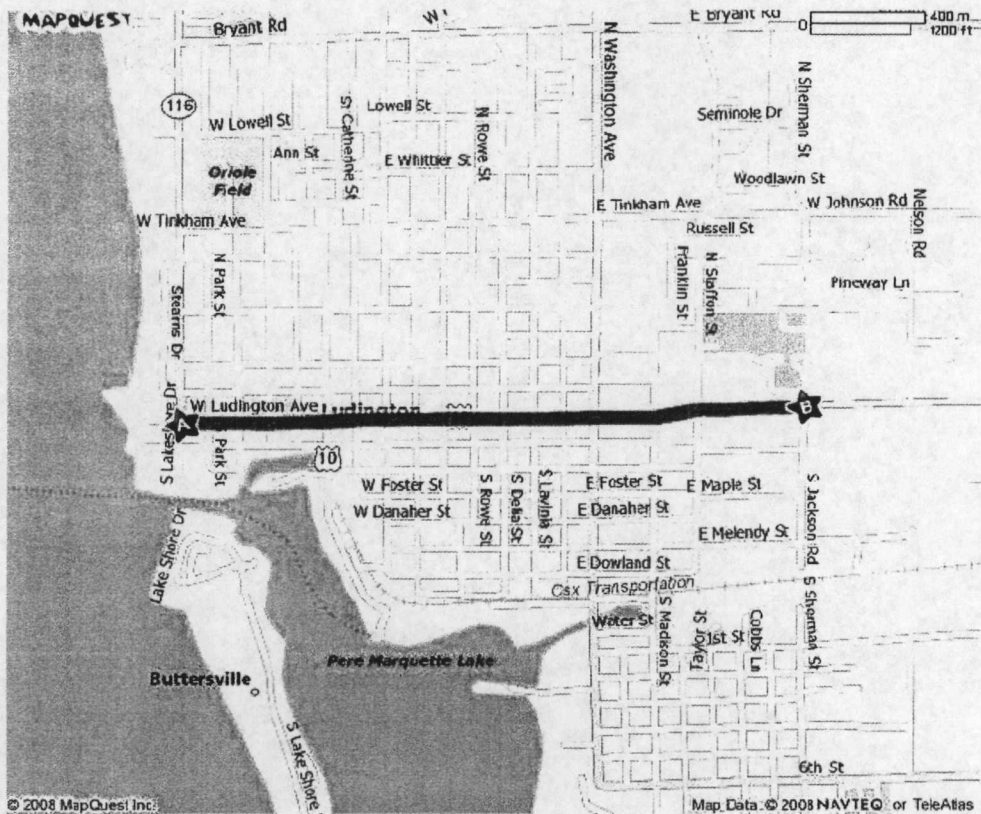
\_\_\_\_\_

\_\_\_\_\_

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## Appendix E

Map to the Hospital



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## Appendix F

Job Safety Analysis





## JOB SAFETY ANALYSIS

## SECTION 1

<b>JSA Type:</b>	Field Work
<b>JSA No:</b>	JSA001178
<b>Date:</b>	1/9/2008
<b>Work Type:</b>	Environmental
<b>Work Activity:</b>	
<b>Project No.:</b>	

## SECTION 2

Development Team	Position/Title	PC	Reviewed By	Position/Title	Date

### SECTION 3

[illegible]

## SECTION 4

### Personal Protective Equipment (PPE):

Initial - In Progress - 01/09/2008 04:19 PM EST

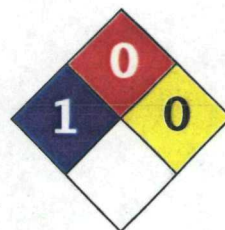
ARCADIS

**Appendix G**

Material Safety Data Sheets



**Science Lab.com**  
Chemicals & Laboratory Equipment



Health	1
Fire	0
Reactivity	0
Personal Protection	E

## Material Safety Data Sheet Lead MSDS

### Section 1: Chemical Product and Company Identification

**Product Name:** Lead

**Catalog Codes:** SLL1291, SLL1669, SLL1081, SLL1459, SLL1834

**CAS#:** 7439-92-1

**RTECS:** OF7525000

**TSCA:** TSCA 8(b) inventory: Lead

**CI#:** Not available.

**Synonym:** Lead Metal, granular; Lead Metal, foil; Lead Metal, sheet; Lead Metal, shot

**Chemical Name:** Lead

**Chemical Formula:** Pb

#### Contact Information:

**Sciencelab.com, Inc.**  
14025 Smith Rd.  
Houston, Texas 77396

US Sales: **1-800-901-7247**  
International Sales: **1-281-441-4400**

Order Online: [ScienceLab.com](http://ScienceLab.com)

**CHEMTREC (24HR Emergency Telephone), call:**  
1-800-424-9300

**International CHEMTREC, call:** 1-703-527-3887

**For non-emergency assistance, call:** 1-281-441-4400

### Section 2: Composition and Information on Ingredients

#### Composition:

Name	CAS #	% by Weight
Lead	7439-92-1	100

**Toxicological Data on Ingredients:** Lead LD50: Not available. LC50: Not available.

### Section 3: Hazards Identification

**Potential Acute Health Effects:** Slightly hazardous in case of skin contact (irritant), of eye contact (irritant), of ingestion, of inhalation.

#### Potential Chronic Health Effects:

Slightly hazardous in case of skin contact (permeator).

**CARCINOGENIC EFFECTS:** Classified A3 (Proven for animal.) by ACGIH, 2B (Possible for human.) by IARC.

**MUTAGENIC EFFECTS:** Not available.

**TERATOGENIC EFFECTS:** Not available.

**DEVELOPMENTAL TOXICITY:** Not available.

The substance may be toxic to blood, kidneys, central nervous system (CNS).

Repeated or prolonged exposure to the substance can produce target organs damage.

#### Section 4: First Aid Measures

**Eye Contact:**

Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Get medical attention if irritation occurs.

**Skin Contact:** Wash with soap and water. Cover the irritated skin with an emollient. Get medical attention if irritation develops.

**Serious Skin Contact:** Not available.

**Inhalation:**

If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention.

**Serious Inhalation:** Not available.

**Ingestion:**

Do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. If large quantities of this material are swallowed, call a physician immediately. Loosen tight clothing such as a collar, tie, belt or waistband.

**Serious Ingestion:** Not available.

#### Section 5: Fire and Explosion Data

**Flammability of the Product:** May be combustible at high temperature.

**Auto-Ignition Temperature:** Not available.

**Flash Points:** Not available.

**Flammable Limits:** Not available.

**Products of Combustion:** Some metallic oxides.

**Fire Hazards in Presence of Various Substances:** Non-flammable in presence of open flames and sparks, of shocks, of heat.

**Explosion Hazards in Presence of Various Substances:**

Risks of explosion of the product in presence of mechanical impact: Not available.

Risks of explosion of the product in presence of static discharge: Not available.

**Fire Fighting Media and Instructions:**

SMALL FIRE: Use DRY chemical powder.

LARGE FIRE: Use water spray, fog or foam. Do not use water jet.

**Special Remarks on Fire Hazards:** When heated to decomposition it emits highly toxic fumes of lead.

**Special Remarks on Explosion Hazards:** Not available.

#### Section 6: Accidental Release Measures

**Small Spill:**

Use appropriate tools to put the spilled solid in a convenient waste disposal container. Finish cleaning by spreading water on the contaminated surface and dispose of according to local and regional authority requirements.

**Large Spill:**

Use a shovel to put the material into a convenient waste disposal container. Finish cleaning by spreading water on the contaminated surface and allow to evacuate through the sanitary system. Be careful that the product is not

present at a concentration level above TLV. Check TLV on the MSDS and with local authorities.

## Section 7: Handling and Storage

### Precautions:

Keep locked up.. Keep away from heat. Keep away from sources of ignition. Empty containers pose a fire risk, evaporate the residue under a fume hood. Ground all equipment containing material. Do not ingest. Do not breathe dust. Wear suitable protective clothing. If ingested, seek medical advice immediately and show the container or the label. Keep away from incompatibles such as oxidizing agents.

**Storage:** Keep container tightly closed. Keep container in a cool, well-ventilated area.

## Section 8: Exposure Controls/Personal Protection

### Engineering Controls:

Use process enclosures, local exhaust ventilation, or other engineering controls to keep airborne levels below recommended exposure limits. If user operations generate dust, fume or mist, use ventilation to keep exposure to airborne contaminants below the exposure limit.

**Personal Protection:** Safety glasses. Lab coat. Dust respirator. Be sure to use an approved/certified respirator or equivalent. Gloves.

### Personal Protection in Case of a Large Spill:

Splash goggles. Full suit. Dust respirator. Boots. Gloves. A self contained breathing apparatus should be used to avoid inhalation of the product. Suggested protective clothing might not be sufficient; consult a specialist BEFORE handling this product.

### Exposure Limits:

TWA: 0.05 (mg/m3) from ACGIH (TLV) [United States]

TWA: 0.05 (mg/m3) from OSHA (PEL) [United States]

TWA: 0.03 (mg/m3) from NIOSH [United States]

TWA: 0.05 (mg/m3) [Canada] Consult local authorities for acceptable exposure limits.

## Section 9: Physical and Chemical Properties

**Physical state and appearance:** Solid. (Metal solid.)

**Odor:** Not available.

**Taste:** Not available.

**Molecular Weight:** 207.21 g/mole

**Color:** Bluish-white. Silvery. Gray

**pH (1% soln/water):** Not applicable.

**Boiling Point:** 1740°C (3164°F)

**Melting Point:** 327.43°C (621.4°F)

**Critical Temperature:** Not available.

**Specific Gravity:** 11.3 (Water = 1)

**Vapor Pressure:** Not applicable.

**Vapor Density:** Not available.

**Volatility:** Not available.

**Odor Threshold:** Not available.

**Water/Oil Dist. Coeff.:** Not available.

**Ionicity (in Water):** Not available.

**Dispersion Properties:** Not available.

**Solubility:** Insoluble in cold water.

## Section 10: Stability and Reactivity Data

**Stability:** The product is stable.

**Instability Temperature:** Not available.

**Conditions of Instability:** Incompatible materials, excess heat

**Incompatibility with various substances:** Reactive with oxidizing agents.

**Corrosivity:** Non-corrosive in presence of glass.

**Special Remarks on Reactivity:**

Can react vigorously with oxidizing materials.

Incompatible with sodium carbide, chlorine trifluoride, trioxane + hydrogen peroxide, ammonium nitrate, sodium azide, disodium acetylide, sodium acetylide, hot concentrated nitric acid, hot concentrated hydrochloric acid, hot concentrated sulfuric acid, zirconium.

**Special Remarks on Corrosivity:** Not available.

**Polymerization:** Will not occur.

## Section 11: Toxicological Information

**Routes of Entry:** Absorbed through skin. Inhalation. Ingestion.

**Toxicity to Animals:**

LD50: Not available.

LC50: Not available.

**Chronic Effects on Humans:**

CARCINOGENIC EFFECTS: Classified A3 (Proven for animal.) by ACGIH, 2B (Possible for human.) by IARC.

May cause damage to the following organs: blood, kidneys, central nervous system (CNS).

**Other Toxic Effects on Humans:** Slightly hazardous in case of skin contact (irritant), of ingestion, of inhalation.

**Special Remarks on Toxicity to Animals:** Not available.

**Special Remarks on Chronic Effects on Humans:** Not available.

**Special Remarks on other Toxic Effects on Humans:**

Acute Potential:

Skin:

Lead metal granules or dust: May cause skin irritation by mechanical action.

Lead metal foil, shot or sheets: Not likely to cause skin irritation

Eyes:

Lead metal granules or dust: Can irritate eyes by mechanical action.

Lead metal foil, shot or sheets: No hazard. Will not cause eye irritation.

**Inhalation:**

In an industrial setting, exposure to lead mainly occurs from inhalation of dust or fumes.

Lead dust or fumes: Can irritate the upper respiratory tract (nose, throat) as well as the bronchi and lungs by mechanical action. Lead dust can be absorbed through the respiratory system. However, inhaled lead does not accumulate in the lungs. All of an inhaled dose is eventually absorbed or transferred to the gastrointestinal tract. Inhalation effects of exposure to fumes or dust of inorganic lead may not develop quickly. Symptoms may include metallic taste, chest pain, decreased physical fitness, fatigue, sleep disturbance, headache, irritability, reduces memory, mood and personality changes, aching bones and muscles, constipation, abdominal pains, decreasing appetite. Inhalation of large amounts may lead to ataxia, delirium, convulsions/seizures, coma, and death.

Lead metal foil, shot, or sheets: Not an inhalation hazard unless metal is heated. If metal is heated, fumes will be released. Inhalation of these fumes may cause "fume metal fever", which is characterized by flu-like symptoms. Symptoms may include metallic taste, fever, nausea, vomiting, chills, cough, weakness, chest pain, generalized muscle pain/aches, and increased white blood cell count.

**Ingestion:**

Lead metal granules or dust: The symptoms of lead poisoning include abdominal pain or cramps (lead colic), spasms, nausea, vomiting, headache, muscle weakness, hallucinations, distorted perceptions, "lead line" on the gums, metallic taste, loss of appetite, insomnia, dizziness and other symptoms similar to that of inhalation. Acute poisoning may result in high lead levels in the blood and urine, shock, coma and death in extreme cases.

Lead metal foil, shot or sheets: Not an ingestion hazard for usual industrial handling.

## Section 12: Ecological Information

**Ecotoxicity:** Not available.

**BOD5 and COD:** Not available.

**Products of Biodegradation:**

Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.

**Toxicity of the Products of Biodegradation:** The products of degradation are less toxic than the product itself.

**Special Remarks on the Products of Biodegradation:** Not available.

## Section 13: Disposal Considerations

**Waste Disposal:**

Waste must be disposed of in accordance with federal, state and local environmental control regulations.

## Section 14: Transport Information

**DOT Classification:** Not a DOT controlled material (United States).

**Identification:** Not applicable.

**Special Provisions for Transport:** Not applicable.

## Section 15: Other Regulatory Information

**Federal and State Regulations:**

California prop. 65: This product contains the following ingredients for which the State of California has found to cause cancer, birth defects or other reproductive harm, which would require a warning under the statute: Lead

California prop. 65: This product contains the following ingredients for which the State of California has found to cause reproductive harm (female) which would require a warning under the statute: Lead

California prop. 65: This product contains the following ingredients for which the State of California has found to



cause reproductive harm (male) which would require a warning under the statute: Lead  
California prop. 65 (no significant risk level): Lead: 0.0005 mg/day (value)  
California prop. 65: This product contains the following ingredients for which the State of California has found to cause birth defects which would require a warning under the statute: Lead  
California prop. 65: This product contains the following ingredients for which the State of California has found to cause cancer which would require a warning under the statute: Lead  
Connecticut hazardous material survey.: Lead  
Illinois toxic substances disclosure to employee act: Lead  
Illinois chemical safety act: Lead  
New York release reporting list: Lead  
Rhode Island RTK hazardous substances: Lead  
Pennsylvania RTK: Lead

**Other Regulations:**

OSHA: Hazardous by definition of Hazard Communication Standard (29 CFR 1910.1200).  
EINECS: This product is on the European Inventory of Existing Commercial Chemical Substances.

**Other Classifications:**

**WHMIS (Canada):** CLASS D-2A: Material causing other toxic effects (VERY TOXIC).

**DSCL (EEC):**

R20/22- Harmful by inhalation and if swallowed.  
R33- Danger of cumulative effects.  
R61- May cause harm to the unborn child.  
R62- Possible risk of impaired fertility.  
S36/37- Wear suitable protective clothing and gloves.  
S44- If you feel unwell, seek medical advice (show the label when possible).  
S53- Avoid exposure - obtain special instructions before use.

**HMIS (U.S.A.):**

**Health Hazard:** 1

**Fire Hazard:** 0

**Reactivity:** 0

**Personal Protection:** E

**National Fire Protection Association (U.S.A.):**

**Health:** 1

**Flammability:** 0

**Reactivity:** 0

**Specific hazard:**

**Protective Equipment:**

Gloves.  
Lab coat.  
Dust respirator. Be sure to use an approved/certified respirator or equivalent. Wear appropriate respirator when ventilation is inadequate.



Safety glasses.

## Section 16: Other Information

**References:** Not available.

**Other Special Considerations:** Not available.

**Created:** 10/10/2005 08:21 PM

**Last Updated:** 10/10/2005 08:21 PM

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## Section 1 - Chemical Product and Company Identification

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**Material Name:** Fuel Oil No. 2

**CAS Number:** 68476-30-2

**Chemical Formula:** Un; Va

**Structural Chemical Formula:** Unspecified; Variable

**EINECS Number:** 270-671-4

**ACX Number:** X1010102-3

**Synonyms:** #2 HOME HEATING OILS; API NO. 2 FUEL OIL; FUEL OIL NO. 2; FUEL OIL, NO. 2; GAS OIL; HOME HEATING OIL NO.2; NUMBER 2 BURNER FUEL; NUMBER 2 FUEL OIL

**Derivation:** Residue from distillation (straight run or cracked) of crude oil.

**General Use:** Used as a fuel in atomizing burners for domestic and industrial heating, in engines of heavy units (ships, trucks, trains), as a source of synthesis gas, in drilling muds, and for mosquito control (coats breeding waters).

## Section 2 - Composition / Information on Ingredients

Name	CAS	%
Fuel oil no. 2	68476-30-2	ca 100% vol
(complex mixture (< 95%) of paraffinic, olefinic, naphthenic, and aromatic hydrocarbons)		
<b>Trace Impurities:</b> water and sediment (< 0.05% vol), carbon residue (< 0.35%), ash (< 0.01% wt), sulfur (< 0.7% wt) and benzene (< 100 ppm).		

**OSHA PEL**

**NIOSH REL**

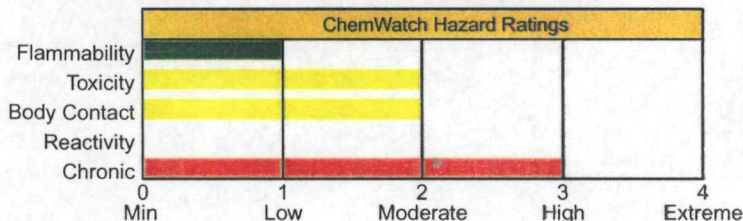
**ACGIH TLV**

TWA: 100 mg/m<sup>3</sup>; skin.

## Section 3 - Hazards Identification



Fire Diamond



HMIS	
1	Health
2	Flammability
0	Reactivity

**ANSI Signal Word**

**Warning!**



Flammable

### ☆☆☆☆☆ Emergency Overview ☆☆☆☆☆

Amber to brown, slightly viscous liquid; petroleum odor. Irritating to skin/respiratory tract. Other Acute Effects: aspiration hazard, chemical pneumonitis, respiratory failure, vomiting, diarrhea, CNS depression, increased respiration, rapid heart beat, cyanosis. Flammable.

### Potential Health Effects

**Target Organs:** Skin, CNS, cardiovascular system (CVS), respiratory system, mucous membranes

**Primary Entry Routes:** Inhalation, ingestion

**Acute Effects**

**Inhalation:** Respiratory tract irritation, headache, dizziness, euphoria, nausea, increased respiration rate, tachycardia (excessively rapid heart beat), cyanosis, stupor, convulsions, and unconsciousness can result from inhalation of fuel oil no. 2 mist.

**Eye:** Contact may result in irritation.

**Skin:** Contact may cause irritation.



**Ingestion:** Gastrointestinal irritation, vomiting, diarrhea, and in severe cases, CNS depression, progressing to coma and death, can result. Since intestinal absorption of longer chain hydrocarbons is minimal, aspiration into lungs following ingestion is a more significant exposure route; it may result in transient CNS depression, hemorrhaging and pulmonary edema, progressing to renal (kidney) involvement, chemical pneumonitis, and respiratory failure.

**Carcinogenicity:** NTP - Not listed; IARC - Group 3, Not classifiable as to carcinogenicity to humans; OSHA - Not listed; NIOSH - Not listed; ACGIH - Not listed; EPA - Not listed; MAK - Not listed.

**Medical Conditions Aggravated by Long-Term Exposure:** None reported.

**Chronic Effects:** Prolonged and repeated skin contact can cause dermatitis, irritate the hair follicles and may block the (oil) sebaceous glands, producing a rash of acne pimples, usually on the arms and legs. Repeated exposures producing CNS effects may lead to permanent nervous system damage.

### Section 4 - First Aid Measures

**Inhalation:** Remove exposed person to fresh air and support breathing as needed.

**Eye Contact:** *Do not* allow victim to rub or keep eyes tightly shut. Gently lift eyelids and flush immediately and continuously with flooding amounts of water for at least 15 minutes. Consult a physician or ophthalmologist if pain and/or irritation develop.

**Skin Contact:** Quickly remove contaminated clothing. Rinse with flooding amounts of water followed by washing the exposed area with soap and water. For reddened or blistered skin, consult a physician.

**Ingestion:** Never give anything by mouth to an unconscious or convulsing person. Contact a poison control center. *Do not* induce vomiting unless the poison control center advises otherwise.

*After first aid, get appropriate in-plant, paramedic, or community medical support.*

**Note to Physicians:** Gastric lavage for treatment of ingestion is contraindicated due to aspiration hazard. Administer charcoal slurry cathartic (30 g/240 mL diluent). In cases of severe aspiration pneumonitis, consider monitoring arterial blood gases and obtain chest x-ray.

See  
DOT  
ERG

### Section 5 - Fire-Fighting Measures

**Flash Point:** 136 °F (57.78 °C), Closed Cup

**Autoignition Temperature:** 494 °F (257 °C)

**LEL:** 0.6% v/v

**UEL:** 7.5% v/v

**Flammability Classification:** OSHA Class II Combustible Liquid.

**Extinguishing Media:** Use dry chemical, carbon dioxide, foam, water fog or spray. Water may be ineffective in putting out a fire involving fuel oil no. 2, and a solid water stream may spread the flames; however, a water spray may be used to cool fire-exposed containers, and flush spills away from ignition sources.

**General Fire Hazards/Hazardous Combustion Products:** Heating fuel oil no. 2 to decomposition can produce thick acrid smoke and irritating fumes. Can form explosive mixtures in air. In still air, the heavier-than-air vapors of fuel oil no. 2 may travel along low-lying surfaces to distant sources of ignition and flash back to the material source. Containers may explode in heat of fire.

**Fire-Fighting Instructions:** If tank, rail car or tank truck is involved in fire isolate for 1/2 mile (800 m). *Do not* release runoff from fire control methods to sewers or waterways. Because fire may produce toxic thermal decomposition products, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in pressure-demand or positive-pressure mode.

See  
DOT  
ERG



Fire Diamond

### Section 6 - Accidental Release Measures

**Spill/Leak Procedures:** Eliminate all ignition sources (no smoking, flares, sparks or flames in immediate area). All equipment used when handling the product must be grounded. *Do not* touch or walk through spilled material. Stop leak if you can do it without risk. Prevent entry into waterways, sewers, basements or confined areas. Isolate area for at least 80-160 ft (25-50 m) in all directions.

Water spray or fire fighting foam may suppress vapor, but may not prevent ignition in closed spaces. Use natural barriers or oil spill control booms to confine oil slicks on surface water.

**Small Spills:** Absorb fuel oil no. 2 with vermiculite, earth, sand or similar material.

**Large Spills:** For large spills, consider downwind evacuation of at least 1000 ft (300 m). Dike far ahead of liquid spill for later disposal. *Do not* release into sewers or waterways. Ground all equipment. Spills can be absorbed with materials such as peat, activated carbon, polyurethane foam, or straw. Sinking agents, gelling agents, dispersants, and mechanical systems can also be used to treat oil spills. Use clean non-sparking tools to collect absorbed material.

**Regulatory Requirements:** Follow applicable OSHA regulations (29 CFR 1910.120).

See  
DOT  
ERG

## Section 7 - Handling and Storage

**Handling Precautions:** Avoid vapor or mist inhalation, and skin and eye contact. Use only with ventilation sufficient to reduce airborne concentrations as low as possible. Wear protective gloves (or use barrier cream) and clothing (see Sec. 8). Keep away from heat and ignition sources. Ground and bond all containers during transfers to prevent static sparks. Use non-sparking tools to open and close containers.

Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

**Recommended Storage Methods:** Store in tightly closed container in cool, well-ventilated area, away from heat, ignition sources and incompatibles (See Sec. 10). Periodically inspect stored materials. Equip drums with self-closing valves, pressure vacuum bungs, and flame arrestors.

**Regulatory Requirements:** Follow applicable OSHA regulations. Also 29 CFR 1910.106 for a Class II Combustible Liquid.

## Section 8 - Exposure Controls / Personal Protection

**Engineering Controls:** To prevent static sparks, electrically ground and bond all containers and equipment used in shipping, receiving, or transferring operations. Provide general or local exhaust ventilation systems to maintain airborne concentrations as low as possible. Local exhaust ventilation is preferred because it prevents contaminant dispersion into the work area by controlling it at its source.

**Administrative Controls:** Enclose operations and/or provide local exhaust ventilation at the site of chemical release designed for flammable vapors/mists. Where possible, transfer fuel oil no. 2 from drums or other storage containers to process containers. Minimize sources of ignition in surrounding low-lying areas.

**Personal Protective Clothing/Equipment:** Wear chemically protective gloves, boots, aprons, and gauntlets of Viton or nitrile rubber, if possible, or alternatively, polyvinyl chloride, chlorinated polyethylene or neoprene to prevent skin contact. Butyl rubber may degrade after contact and is not recommended. Wear protective eyeglasses per OSHA eye- and face-protection regulations (29 CFR 1910.133). Contact lenses are not eye protective devices. Appropriate eye protection must be worn instead of, or in conjunction with contact lenses.

**Respiratory Protection:** Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a MSHA/NIOSH-approved respirator. Select respirator based on its suitability to provide adequate worker protection for given working conditions, level of airborne contamination, and presence of sufficient oxygen. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), use an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.* If respirators are used, OSHA requires a written respiratory protection program that includes at least: medical certification, training, fit-testing, periodic environmental monitoring, maintenance, inspection, cleaning, and convenient, sanitary storage areas.

**Other:** Separate contaminated work clothes from street clothes. Launder before reuse. Remove this material from your shoes and clean personal protective equipment. Make emergency eyewash stations, safety/quick-drench showers, and washing facilities available in work area.

## Section 9 - Physical and Chemical Properties

**Appearance/General Info:** Amber to brown, slightly viscous; petroleum odor.

**Physical State:** Liquid

**Odor Threshold:** Medium odor threshold 0.082 ppm

**Formula Weight:** N/A

**Specific Gravity (H<sub>2</sub>O=1, at 4 °C):** 0.8654 at 59 °F (15 °C)

**Boiling Point:** 450 °F (232 °C)

**Freezing/Melting Point:** -50.8 °F (-46 °C)

**Viscosity:** 268 centistoke at 100 °F (37.8 °C)

**Surface Tension:** 25 dynes/cm, estimated

**Water Solubility:** Slightly soluble

## Section 10 - Stability and Reactivity

**Stability/Polymerization/Conditions to Avoid:** Fuel oil no. 2 is stable at room temperature in closed containers under normal storage and handling conditions. Hazardous polymerization cannot occur. Heat and ignition sources.

**Storage Incompatibilities:** Include strong oxidizing agents.

**Hazardous Decomposition Products:** Thermal oxidative decomposition of fuel oil no. 2 can produce various hydrocarbons, hydrocarbon derivatives, partial oxidation products (carbon dioxide (CO<sub>2</sub>), carbon monoxide (CO), sulfur dioxide (SO<sub>2</sub>)).



**Section 11 - Toxicological Information****Acute Oral Effects:**

Rat, oral, LD<sub>50</sub>: 12 g/kg.

**Acute Skin Effects:**

Rabbit, skin: 100 mL/kg/12 days, continuously, caused irritative dermatitis, weight loss or decreased weight gain, and death.

Rabbit, skin, LD: > 5 g/kg.

**Irritation Effects:**

Rabbit, eye, standard Draize test: 100 mg/30 seconds, resulted in mild irritation.

Rabbit, skin, standard Draize test: 500 mg/24 hr, resulted in moderate irritation.

**Other Effects:**

Tumorigenicity, mouse, skin: 243 g/kg/97 weeks, administered intermittently, caused skin and appendage tumors (carcinogenic by RTECS criteria).

See RTECS LS8930000, for additional data.

**Section 12 - Ecological Information**

**Environmental Fate:** Based on a calculated BCF ( $1.02 \times 10^4$  to  $1.4 \times 10^4$ ), bioconcentration could be an important environmental fate process; however, it may be limited for the chief components of fuel oil no. 2 due to metabolism. It may biodegrade in water and soil, or volatilize from water (half-life of 4.4- 4.8 hours from a model river) and moist soil surfaces, but adsorption may attenuate the rate of these processes. In the atmosphere, fuel oil no. 2 will rapidly degrade by reaction with photochemically produced hydroxyl radicals (estimated half-life 1 day or less). A high  $K_{oc}$  indicates significant sorption and low mobility in the soil column.  $K_{oc} = 1 \times 10^4$ , estimated

**Ecotoxicity:** Juvenile American shad, TL<sub>m</sub>/24 hr: 200 ppm; bluegill, LC<sub>50</sub> = 95 mg/L/96 hr; carp, LC<sub>50</sub> = 8.2 mg/L/24 hr; pumpkin seed, LC<sub>50</sub> = 1.9 mg/L/24 hr. Through its coating action, this material can pose a hazard to aquatic biota including water birds, plankton, algae and fish.

**Henry's Law Constant:** 29 to 68 atm-m<sup>3</sup>/mole at 77 °F (25 °C), estimated

**Octanol/Water Partition Coefficient:** log  $K_{ow}$  = 8.2 to 9.7

**Section 13 - Disposal Considerations**

**Disposal:** Contact your supplier or a licensed contractor for detailed recommendations. Material may be sprayed into an incinerator. Follow applicable Federal, state, and local regulations.

**Section 14 - Transport Information****DOT Hazardous Materials Table Data (49 CFR 172.101):**

**Shipping Name and Description:** Fuel oil (No. 1, 2, 4, 5, or 6)

**ID:** NA1993

**Hazard Class:** 3 - Flammable and combustible liquid

**Packing Group:** III - Minor Danger

**Symbols:** D - Domestic transportation

**Label Codes:** 3 - Flammable Liquid

**Special Provisions:** 144, B1, IB3, T4, TP1, TP29

**Packaging:** Exceptions: 150 Non-bulk: 203 Bulk: 242

**Quantity Limitations:** Passenger aircraft/rail: 60 L Cargo aircraft only: 220 L

**Vessel Stowage:** Location: A Other:

**Section 15 - Regulatory Information****EPA Regulations:**

**RCRA 40 CFR:** Not listed

**CERCLA 40 CFR 302.4:** Not listed

**SARA 40 CFR 372.65:** Not listed

**SARA EHS 40 CFR 355:** Not listed

**TSCA:** Listed


**Section 16 - Other Information**

**Disclaimer:** Judgments as to the suitability of information herein for the purchaser's purposes are necessarily the purchaser's responsibility. Although reasonable care has been taken in the preparation of such information, Genium Group, Inc. extends no warranties, makes no representations, and assumes no responsibility as to the accuracy or suitability of such information for application to the purchaser's intended purpose or for consequences of its use.

ARCADIS

**Appendix H**


Utility Locate Policy and Procedure

 <b>ARCADIS</b> <small>infrastructure. environment. facilities.</small>	<u>ARCADIS HS Procedure Name</u> Utility Location Policy and Procedure	<u>Revision Number</u> 05
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## 1. POLICY

It is the practice of ARCADIS and its affiliated companies to implement appropriate, reasonable and practical procedures within acceptable and customary industry practices to promote the health and safety of its employees, and avoid and mitigate exposure of risk in the performance of their work. In furtherance of this policy, ARCADIS promotes and encourages compliance by all employees with this policy and procedures relating to subsurface work and/or investigations (SWI) and working in the vicinity of above ground utilities.

- This procedure is followed by all responsible ARCADIS personnel. Such procedures are included in the Project Planning processes utilized by ARCADIS personnel.
- Project Management procedural requirements are outlined in Section 5.1. All employees included in SWI and above ground utility work are familiar with these procedures.
- For all SWI, it is required to contact the locality One Call number and/or a privately contracted utility location company, and to conduct a visual inspection of the site for subsurface utility locating. In addition, for non-greenfield sites, ARCADIS obtains from the client, a detailed site utility map. Additional lines of evidence may be required based on field conditions and client requirements for subsurface utility location. The project manager or designated representative in cooperation with the H&S staff and SWI contractor determine when and if additional lines of evidence are required. Additional lines of evidence include but are not limited to the following:
  - Detailed site utility maps, preferably “As-Built” drawings (drawn to scale)
  - Hand augering or digging
  - Hydro-knife
  - Air-knife
  - Radio Frequency Detector (RFD)
  - Ground Penetrating Radar (GPR)
- Contract Terms: In agreements for SWI with a client, prime contractor, or subcontractors, required terms (Exhibit 1) shall be included for the appropriate allocation of risk of damage to subsurface facilities. If such provisions cannot be agreed upon, the reasons are documented and other risk-management actions identified, such as limits of liability, additional physical investigations, additional lines of evidence of utility location, assignment of risk to subcontractors, etc.
- The policy of ARCADIS encourages and empowers all employees to take such action as they deem appropriate to assure compliance with this policy and procedures both in project planning and field site operations. Such authority is delegated to those on the project site to

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immediately stop any SWI work or work in the vicinity of above ground utilities where the employee believes that injury to persons or damage to property could occur. Such action is taken without regard to costs or schedule. Personnel immediately notify their supervisor of any concerns that they have in observing any SWI work or work in the vicinity of above ground utilities. In all agreements between ARCADIS and SWI subcontractors, (e.g., drilling subcontractors), provisions shall be included in the subcontract, work authorization or purchase order. These provisions (Exhibit 1) are found on the ARCADIS intranet at the Legal Department team site.

All ARCADIS personnel involved in SWI work or work in the vicinity of above ground utilities are appropriately trained on this procedure and have the appropriate professional experience for oversight of or involvement in SWI work or work in the vicinity of above ground utilities. ARCADIS Corporate Health & Safety can answer further questions about this policy or the hazards associated with and the control procedure for work in the vicinity of subsurface or above ground utilities.

Again, to support the efforts of ensuring the health and safety of its employees and mitigating risk to ARCADIS, ARCADIS requires that these policies and procedures be followed and implemented at all levels of project management and field implementation.

## 2. PURPOSE AND SCOPE

### 2.1 Purpose

This procedure directs general safety procedures associated with the identification and management of above ground and subsurface utility locations on project sites.


### 2.2 Scope

- 2.2.1 Management Requirements** - ARCADIS personnel managing or working on any project requiring SWI and requiring work in the vicinity of above ground utilities must incorporate this procedure into their project planning and field work activities to ensure that all reasonable means to identify utilities are implemented and that appropriate controls have been put in place to minimize or eliminate damage to these utilities and the hazards associated with these utilities. All applicable procedures described in this document must be completed prior to initiating intrusive field work or field work in the vicinity of above ground utilities, or the work cannot proceed.
- 2.2.2 Project Management Requirements** - Where SWI are required to be performed by a subcontractor to ARCADIS under its subcontract, project management shall require the subcontractor to adequately incorporate SWI procedures described herein into the subcontractor's scope of work.

## 3. DEFINITIONS

**Above Ground Utilities** - For the purpose of this procedure, above ground utilities include, but are not limited to: any above ground line, system, or facility used for producing, storing, conveying, transmitting or distributing communication or telecommunications, electricity, gas,



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petroleum and petroleum products, coal slurry, hazardous liquids or gases, water under pressure, steam, or other hazardous materials.

**Subsurface Utilities** - For the purposes of this procedure, subsurface utilities include, but are not limited to: any underground line, system, or facility used for producing, storing, conveying, transmitting or distributing communication or telecommunications, electricity, gas, petroleum and petroleum products, coal slurry, hazardous liquids or gases, water under pressure, steam, or sanitary sewage; underground storage tanks; tunnels and cisterns; and septic tanks.

#### 4. RESPONSIBILITIES

##### 4.1 Project Manager Responsibilities

To prevent injury to employees, avoid disruption to utility services, and help eliminate damage to subsurface and above ground utilities, project managers have the responsibility for utility identification, location, and marking prior to initiating field activities. Most states, provinces, municipalities, and clients have rules, general statutes, or laws that specify the requirements of subsurface utility location prior to intrusive subsurface field activities (i.e., excavation, trenching, boring, and all forms of drilling operations, etc.). The project manager ensures that these laws are followed, and that the directives outlined in this procedure are met for every project involving SWI and work in the vicinity of above ground utilities.

In addition, if field activities are completed in the vicinity of above ground utilities, the project manager is responsible for working with the client to identify the nature of the utilities, and to determine what control processes need to be implemented to prevent damage to these utilities and to minimize any injury in the event there is damage.

##### 4.2 Field Personnel Responsibilities


Field personnel conducting SWI activities and activities where above ground utilities are in the vicinity of the work have the responsibility to read, understand, and follow this procedure and complete the appropriate checklists during the on-site utility locate process. ARCADIS personnel assisting in the identification of underground utilities have previous related experience of a minimum of 1 year. Those implementing remote sensing technologies have completed training in those techniques and have 6 months experience operating and interpretation results.

If utilities cannot be located to eliminate any reasonable concern, field personnel use their Stop Work authority until utility locations can be identified. Field personnel review this procedure onsite with ARCADIS subcontractors, and ensure they follow the procedures detailed in this document. Any ARCADIS subcontractor not following these procedures are asked to stop work, and the project manager contacted. Any diversion from this procedure by ARCADIS field personnel is approved by the project manager with input from Corporate Health and Safety as necessary.

#### 5. PROCEDURES

##### 5.1 Procedures

A flow chart/decision tree of these procedures is presented in Exhibit 2 of this document.

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### 5.1.1 Project Management Procedural Requirements

#### 5.1.1.1 Planning and Information Request

Field activities are planned and designed to avoid contact with and damage to, and minimize interference with subsurface and above ground utilities in the vicinity of ARCADIS work activities. During the planning phase of a project the project manager contacts the client and/or property owner to request the following information for the area of the Site where the work will occur:

- A list of known or suspected existing and historical subsurface and above ground utilities present on a subject property;
- An accurate site plan (drawn to scale) illustrating subsurface and above ground utilities; and
- Construction, diameter, volume, depth, contents, and physical properties, etc. of each subsurface and above ground utility.


In the event that the client and/or property owner is not aware of the utilities at the subject property, can only provide a partial list, or cannot provide an otherwise accurate, scaled map, plan or drawing of utilities on the site, then additional resources are utilized to identify utilities at the subject property. This may include but are not limited to:

- Contacting utility provider billing departments directly to inquire if a bill is generated for the property address;
- Utilizing city/county computer-drawn maps, or geographical information systems (GIS) data containing utility information; and/or
- A site walk to visually inspect the subject property for evidence of subsurface and above ground utilities (i.e., manhole covers, meters, warning signs, vent pipes, fill ports, pipe runs, utility lines, etc.).

In the project planning process, the project manager and /or task manager determines the reasonable methods to be used to locate subsurface utilities prior to SWI. It is required to contact the state or province One Call number and/or a private utility locator if on private property as appropriate to the site. Also, an additional two lines of evidence are used for subsurface utility line location at all sites. If scaled and accurate site utility maps are not provided by the client, additional lines of evidence are used (see Section 5.0 for lines of evidence options). Increased flexibility is built into subsurface sampling and/or extraction programs when confidence in utility identification, location, and marking is less than optimal.

#### 5.1.1.2 Communication and Coordination

Using list of identified and suspected utilities, the PM or their designated Task Manager:

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- Notifies a public one-call service centers and/or private utility contractors prior to initiating intrusive subsurface field activities;
- Provides the list to the site safety officer for inclusion in the site-specific health and safety plan (HASP);
- Communicates potential hazards to field staff prior to mobilization;
- Instructs field staff to be aware of and implement the procedures in the Section 6.2 of this procedure and utilize the appropriate utility location checklists.
- When practical, schedules a joint meeting between the public/private utility locators and field staff to oversee the subsurface utility locating and marking in the field.
- Communicates with and provides utility location documentation to the subcontractors to inform them of the utility locations and discusses methods to be used to protect those utilities.
- Understands the subcontractor's methods for utility location and documenting the process with a clear delineation of responsibilities for utility location.

In general, subsurface utility locations marked by public utility locators are only good for 2 weeks (research your state-specific requirements). If SWI activities are not conducted during this time period, the site is remarked. At no time is SWI conducted based on old markings, hand-drawn maps/sketches, photographs, or by recollection/memory of field staff. If markings are smeared, removed, damaged, or impacted in any way, the site must be remarked before SWI begins. Flag markings are used in addition to paint markings wherever possible.

#### 5.1.1.3 Utility Request Notifications for Public Property

Prior to intrusive work on public property (i.e., right-of-ways, easements, etc.), notification of a public one-call service center is completed a minimum of 48-72 hours (states/localities requirements vary, so the PM is responsible for verifying this) prior to initiating field activities (excluding Saturdays, Sundays, and legal holidays). Specific state or local laws related to utility location are evaluated with respect to notification and liability in the event of utility damage. During the call, ARCADIS:

- Provides accurate description of the location of all areas of the SWI;
- Documents the utility locate request to record the time and date of the call, the area to be marked, the list of utility companies and municipalities that the one call service center will notify;

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- Records the associated ticket (or dig) number provided by the one call service center;
- Cross references the notification list provided by the one-call service center with the list of known or suspected utilities for the property; and
- Provides accurate contact (PM name and phone numbers) information for the one call service center so they can subsequently communicate potential questions and/or delays related to the utility location and marking.


After receiving a request, the one-call service center sends requests to participating utility operators who have utilities in the area of the intrusive field activities. Each underground utility operator dispatches their own locators to mark their facilities with paint or flags. The project manager attempts to have field staff present during the marking of the utilities by the locator organization to ensure that the area of the SWI is included in the locating activities. It is important to note:

- Not all utility operators and municipalities participate in one call programs. In some instances, one-call programs provide a list of utility providers that participate, and a list of those that do not. The utility providers that do not participate are contacted individually so that they can mark their own lines, and ARCADIS documents this call (date of call, person receiving call, date lines will be marked, etc.);
- Public utility locators are usually only required to mark utilities within the public spaces (i.e., right of ways) or at most up to a meter on private property; and
- Knowledge of existing or suspected, but unmarked utilities are documented and communicated to the site safety officer, field staff, and the client prior to implementing field activities.

If a known or suspected subsurface utility does not participate in the state one-call program, and that provider has not been individually contacted prior to the start of SWI, then the field activities are postponed. If these utility providers are contacted and do not provide utility location services, then SWI are not performed until a private utility locating company is contracted and the locating tasks completed. If utility locates are not completed by public or private utility locating companies, then the subsurface activities are performed with extreme care using hand tools, or other means of utility location are used (air knife/hydro-knife technologies, or GPR), but only upon receiving approval from the ARCADIS Health & Safety department and the client.

#### *5.1.1.4 Utility Request Notifications for Private Property, Military Installations, or Other Government Facilities*

Prior to intrusive work on private property, military installations, or other government facilities the public one call service center is contacted as previously described, to identify utilities that enter and/or are in the vicinity of the subject property. In addition,


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- A private utility contractor may be required to locate and mark utilities that transect the property beyond meters and/or additional utilities that property owner has installed, which may or may not be maintained and serviced by a utility or municipality
- Where appropriate, or at a client's request, a facility or plant engineer familiar with the subsurface utilities is contacted to request marking and location of utilities
- One or more weeks of advanced notice is usually required to subcontract a private contractor or coordinate with a facility or plant engineer to locate and mark utilities
- Verbal or written requests to private contractors or onsite personnel for utility location and marking is documented to record the time and date of the request, the area to be marked, and the list of utilities to be marked
- The project manager attempts to have field staff present during the marking of the utilities by the locator organization to ensure that the area of the SWI is included in the locating activities
- Knowledge of existing or suspected, but unmarked utilities is documented and communicated to the site safety officer, field staff, and the client prior to implementing field activities
- If a known or suspected utility is not located and marked by the private utility company or facility engineer, then sampling and/or excavation activities is performed with extreme care using hand tools, hydro-knife or other method that does not damage the utility; postponed until utilities are clearly marked; or canceled. If work proceeds, it can only be completed with the approval of the ARCADIS Health and Safety department and the client.

#### 5.1.1.5 New Nation-wide Utility Locate Call Number 811

Several state and local utility notification centers have launched a new "Call before you Dig" number to help save lives and protect underground infrastructure. This new, national number is: **811**. The number is designed to help prevent professional excavators, drillers, etc. and homeowners, from damaging underground utility lines while digging/drilling and causing injury or service outage. For more information about the 811 services, visit [www.call811.com](http://www.call811.com)

The number 811 is a new FCC designated national n-11 number created to eliminate confusion of multiple calls before you dig numbers across the country. This quick and efficient one call service will notify the appropriate utilities, who participate in the one call program. **However**, ARCADIS callers must still verify who the one call service contacts, and then determine which utilities may need to be contacted directly (e.g. those utilities not participating in the one call service) by following the requirements outlined in this procedure.

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### 5.1.2 Field Protocol

At no time do field activities that involve SWI or work in the vicinity of above ground utilities commence without the field staff having knowledge of the location of subsurface and above ground utilities. In addition, as stated above and in general, subsurface utility locations marked by public utility locators are only good for 2 weeks (research your state-specific requirements). If SWI activities are not conducted during this time period, the site is remarked. At no time is SWI conducted based on old markings, hand-drawn maps/sketches, photographs, or by recollection/memory of field staff. If markings are smeared, removed, damaged, or impacted in any way, the site must be remarked before SWI begins. Flag markings are used in addition to paint markings wherever possible.

#### 5.1.2.1 SWI and Subsurface Utilities

Prior to the start of intrusive activities, all utilities are located and measures instituted to avoid subsurface utility hazards. If intrusive work must take place within close proximity to a utility line, the utility line can also be rendered controlled (i.e. through lockout/tagout procedures).


Prior to mobilizing to the site for SWI work, field staff reviews the task details with the project manager or their designated authorized TM. This may include but is not limited to review of boring logs, excavation permits, etc. Any special site or client requirements are also discussed. Prior to initiation of any intrusive activities, the utilities and structures checklist (Exhibit 3) is reviewed and completed. Generally, the following colors apply for different types of utilities/operations:

- Red – Electric;
- Yellow – Natural gas/oil;
- Orange – Communication/cable television;
- Blue – Water;
- Green – Sewer;
- Pink – Temporary survey marking;
- White – Proposed excavation; and
- Purple – Reclaimed water

In addition, the SWI subcontractor marks (i.e., paint, stakes, etc.) the location of their operations to ensure they fall within the area that has been investigated for utilities.

Once the checklist is completed and all utilities identified, any client/site specific utility location or other utility (subsurface or above ground utilities) protection procedures (i.e. such as hand digging to a specified depth, covering or shielding lines, etc.) is completed at each location where work will be completed. If a known or suspected public subsurface utility has not been marked or the markings are not clear, the state one-call number is contacted to determine if an "emergency" locate can be requested. If so, follow the procedures outlined by the locate service and contact the project manager. If it is a private utility that is not marked, the facility manager and/or the project manager should be contacted.

If uncertainty remains on utility location, and/or more precise locations of utilities are required, and where field staff determine the circumstances warrant it, additional lines of evidence are implemented including air or hydro knifing, or ground penetrating radar. Descriptions of the use and limitations of these methods are included in Exhibit 4.

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If unexpected conditions are encountered (refusal, debris, pea gravel, etc.) while completing the intrusive activity, all work is immediately halted. Note that subsurface utilities at many industrial facilities are often placed in conduits or concrete to prevent damage. If a utility or subsurface structure is compromised, the field staff initiates the Emergency Action Plan Guidelines (Exhibit 5); however, more detailed emergency action procedures should be reviewed with the client and documented in the site specific health and safety plan prior to initiating work.

#### 5.1.2.2 Work in the Vicinity of Above Ground Utilities


If activities take place in the vicinity of an above ground utility, the utility line can be rendered controlled (i.e. through lockout/tagout procedures) or protected from damage (i.e. covering overhead power lines). The following table is used to develop acceptable work distances for work involving machinery with high extensions (backhoes, drilling rig masts, etc.) in the vicinity of overhead power lines:

Power Line Voltage Phase to phase (kV)	Minimum Safe Clearance (feet)
50 or below	10
Above 50 to 200	15
Above 200 to 350	20
Above 350 to 500	25
Above 500 to 750	35
Above 750 to 1,000	45

*ANSI Standard B30.5-1994, 5-3.4.5*

The distance may be lengthened if directed by the client or the electric company, and any specified distances are strictly followed. In addition, work involving machinery, vehicles or equipment that may come in contact with above ground utilities is not completed until those utilities are protected or control processes are in place to avoid damage to those utilities.

If an above ground utility is discovered that has not been previously identified prior to mobilizing to the field, the field staff notifies the project manager who requests the client to assist in the identification of the utility and the implementation of control procedures as appropriate. In addition, if a utility or subsurface structure is compromised, the field staff initiates the Emergency Action Plan Guidelines (Exhibit 5); however, more detailed emergency action procedures should be reviewed with the client and documented in the site specific health and safety plan prior to initiating work.

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## 6. RECORDS

### 6.1 Checklist Records

## 7. APPROVALS AND HISTORY OF CHANGE


Approved By: Mija Coppola, Director H&S Compliance Assurance, LPS

*Mija A. Coppola*

### History of Change

Revision Date	Revision Number	Reason for change
13 December 2006	01	Original document
26 March 2007	02	Put in new company format
15 May 2007	03	Added nation-wide 811 number
6 September 2007	04	Changing over to new template format
22 February 2008	05	Changing over to new template format



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### Exhibit 1 - Contract Term Language

**INSERT INTO ALL CLIENT CONTRACTS OR WORK ORDERS WHERE DRILLING, EXCAVATION, INTRUSIVE WORK IS TO BE PERFORMED.**

**Site Conditions:** ARCADIS shall not be liable for: (i) damage or injury to any subterranean structures (including, but not limited to, utilities, mains, pipes, tanks, and telephone cables) or any existing subterranean conditions; or the consequences of such damage or injury, if (with respect to this clause (i)) such structures or conditions were unknown and were not identified or shown, or were incorrectly shown, in information or on plans furnished to or obtained by ARCADIS in connection with the Services; (ii) concealed conditions encountered in the performance of the Services; (iii) concealed or unknown conditions in an existing structure at variance with the conditions indicated by the Scope of Services or Work Authorization; or (iv) unknown physical conditions below the surface of the ground that differ materially from those ordinarily encountered and are generally recognized as inherent in work of the character provided under this Agreement.


Client shall provide to ARCADIS all plans, maps, drawing and other documents identifying the location of any subterranean structures on the Site. Prior to location of any drilling or excavation below the ground surface, ARCADIS shall obtain the concurrence of the Client as to the location for such drilling or excavation.

Should: (i) concealed conditions be encountered in the performance of the Services; (ii) concealed or unknown conditions in an existing structure be at variance with the conditions indicated by the Scope of Services or Work Authorization; or (iii) unknown physical conditions below the surface of the ground differ materially from those ordinarily encountered and generally recognized as inherent in work of the character provided under this Agreement; then the amount of this Agreement and/or time for performance shall be equitably adjusted by change order upon timely notice.

**INSERT INTO ALL DRILLING, EXCAVATION, INTRUSIVE WORK SUBCONTRACTS.**


**Site Conditions:** SUBCONTRACTOR acknowledges that time is of the essence with respect to the performance and completion of its work under this Contract. SUBCONTRACTOR shall adhere to, commence and complete its work in accordance with any schedule incorporated into this Contract, or any schedule submitted by SUBCONTRACTOR or attached hereto; and with respect to any Changes, out of scope or additional work, SUBCONTRACTOR shall expeditiously perform such work according to any schedule therefore agreed to by the parties. In the event any schedule is incorporated in this Contract or attached to this Contract, SUBCONTRACTOR acknowledges and agrees that such schedule has accounted for all inherent or reasonably anticipated delays, including but not limited to those inherent in obtaining site information, access sufficient labor, supplies, tools, equipment and utilities required for the project work, and SUBCONTRACTOR waives any claim of extra compensation or damages therefore.

Subcontractor represents and warrants that it has had an opportunity to review and/or has carefully examined all necessary drawings, maps, schematics, specifications, governmental restrictions, permits and license requirements, and all applicable laws, regulations and rules relating to the Work to be done and the Site, its surroundings and local conditions, and has made all investigations based on reasonably available information that are necessary to develop a full understanding of the hazards and difficulties which can be encountered and are likely to impact the cost or schedule to perform the Work. SUBCONTRACTOR is thus familiar with conditions at the Site as are pertinent to or which may affect the Work and has been granted the right to

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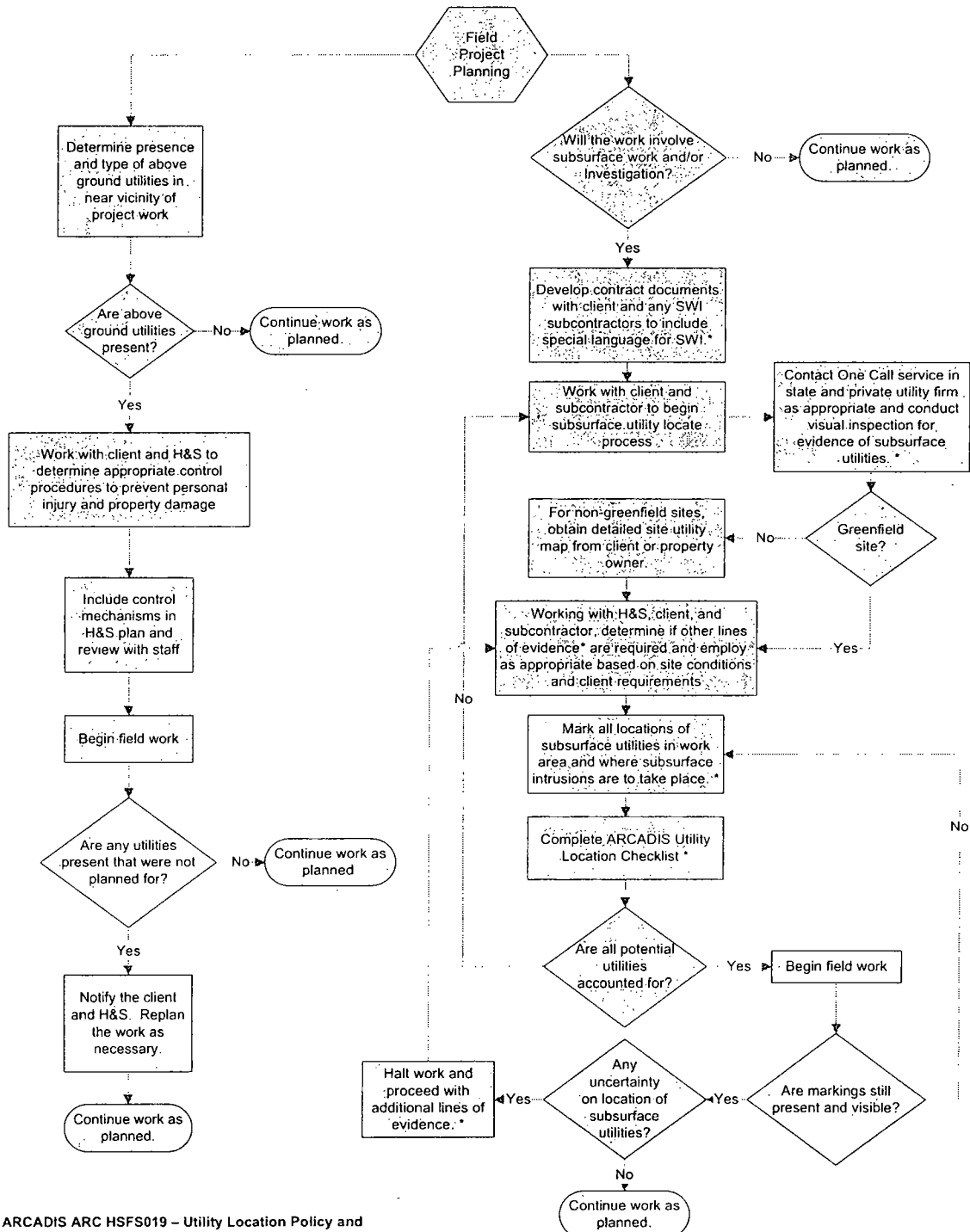
conduct, and has conducted, all investigations it deems appropriate to determine that it can fulfill the requirements of this Contract. Notwithstanding any other provision of this Contract, SUBCONTRACTOR assumes the risk of all conditions, as specified in this Contract, that may affect SUBCONTRACTOR'S ability to perform the Work and will, regardless of such conditions, or the expense or difficulty of performing the Work or the negligence, if any, of ARCADIS, with respect to same, fully complete the Work for the stated price without further recourse to ARCADIS. Information on the Site and local conditions at the Site furnished by ARCADIS are not guaranteed by ARCADIS to be accurate, and is furnished only for the convenience of SUBCONTRACTOR.


The discovery of concealed conditions which could not reasonably have been anticipated by the SUBCONTRACTOR from information available to SUBCONTRACTOR may constitute a changed condition, which, to the extent such condition materially affects the cost or schedule to perform the Work, would entitle the SUBCONTRACTOR to a change and an equitable adjustment of the Contract price or time. SUBCONTRACTOR warrants that it shall conduct appropriate investigations to determine, with reasonable certainty, the location of utility and service lines, underground storage systems, and other subsurface structures of any kind before commencement of any drilling, excavation, or other work that has the potential to disturb these structures. SUBCONTRACTOR further warrants that it shall conduct independent field investigations to confirm the location of subsurface structures before commencement of subsurface work and shall not rely exclusively on plot plans or other drawings provided to SUBCONTRACTOR in conducting these investigations.

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## Exhibit 2 – Utility Location Decision Tree

Exhibit B- Utility Location Decision Tree\*  
 (PMs or TMs are required to follow both sides of flowchart)




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### Exhibit 3 - Utilities and Structures Checklist


<b>Project:</b>	<b>Project Number:</b>
<b>Site Location:</b>	<b>Date:</b>

**Instructions:** This checklist will be used as a safety measure to insure that all underground utility lines, other underground structures as well as above ground utilities are clearly marked out and identified in the area selected for boring or excavation. **DRILLING, EXCAVATION, OR ANY TYPE OF GROUND INTRUSIVE WORK MAY NOT PROCEED UNTIL LINES ARE MARKED AND THIS CHECKLIST HAS BEEN COMPLETED.**

Pre-Field Work Requirements		
Was the state one-call notified with the required advanced notice (usually 48 to 72 hours)	YES	NO
State one-call confirmation number		
What are the 2 lines of evidence used for utility clearance?		
Was a plot plan showing site features and subsurface utilities provided by the PM/TM?	YES	NO
Was the Nation-wide 811 Number called? If no, why not?	YES _____ NO _____	
If yes, what information was provided?		
Subgrade Utility Line Location		
Where is the gas line located?		
Where is the gas meter located on the site building(s)?		
Are the electric lines subsurface or overhead? Where are they located?		
Where is electric meter located on the site building(s)?		
Where are the telephone/cable lines located? Are there any overhead lines?		
Where do these lines enter the site building(s)?		

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Where are the water lines located?	
Does the site occupant use water (bathrooms, industrial uses, fire suppression, etc.)? If so where do the water lines enter the building for these purposes?	
Are there small manholes/vault covers indicating water lines? If so, where?	
Was the local municipality contacted to mark sanitary lines?	
Where are the sanitary lines located?	
Where might the sanitary lines enter the building? (i.e. what side of the building are the bathrooms, kitchens, water treatment plant, etc?)	
Where are the storm sewer lines located?	
Are there storm sewer inlets located on the property? Check inlets for direction of subsurface lines.	
Are there any gutters directing storm water to the subsurface? Evaluate for direction of lines.	
<b>Underground Storage Tank Sites</b>	
Where are the USTs located? How many USTs are at the site (very number of USTs by counting fill ports and vent lines)?	
Where do the vent lines run?	
Where does the piping run? (Evaluate the path between USTs to dispenser islands).	
Where are the sub-surface electrical lines located which feed power to the UST system?	
<b>General Underground Utility Location Signs</b>	
Are there any cracks resembling straight lines that may indicate the settling of utility lines?	
Are there any patched areas where subsurface repairs may have been conducted?	
Are there any manhole covers or valve boxes that are not associated with marked lines?	

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<b>Above ground Utility Line Location</b>	
Are there overhead power lines? If, so where are they located?	
What is the voltage of the overhead power lines?	
Are there any above ground structures (utilities, piping, etc.) that are used by the client? If so, are they located proximal to the work area?	
Do these lines need controlled (locked out) or protected prior to starting work?	
<b>Interviews: Site Owners/Occupants MUST be interviewed for location of private utility lines at the site (if practicable) before start of work</b>	
Name of Owner/Occupant.	
How is this person affiliated with the Site?	
Who interviewed Owner/Occupant?	
Date of Interview	
Specific comments that should be noted from the interview:	


**NOTE: If any subsurface utilities listed above are not located, do not proceed with subsurface activities. Contact PM/TM immediately.**

*Name and signature of person who conducted utility line checklist*

\_\_\_\_\_  
Name (print)

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Date

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#### **Exhibit 4 - Use and Limitations of Utility Locating Methods**

##### **Ground Penetrating Radar (GPR)**

The GPR system transmits high frequency electromagnetic waves into the ground and detects the energy reflected back to the surface. Energy is reflected along boundaries that possess different electrical properties. Reflections typically occur at lithologic contacts or where subsurface materials have high electrical contrasts, including metal objects such as underground storage tanks (USTs), drums, and utility pipes. These reflections are detected by the antenna and are processed into an electrical signal that can be used to image the subsurface feature. The GPR data will be reviewed in the field to assist in the delineation of potential piping or other subsurface structures.

The detection of subsurface structures located at the site depends on the electrical properties of the soil and the structure's depth, diameter, and composition. GPR is limited to the detection of smaller diameter pipes with depth. Generally, a pipe must increase in diameter by one 1 inch for each foot in depth to be seen using GPR. Also, plastic piping is more difficult to detect than metal piping using GPR, and caution should be used if plastic utility lines are suspected.

##### **Radio Frequency Detection (RFD)**


This instrument operates on the principle of radio frequency transmission and detection. The transmitter applies a known frequency to the pipe and the receiver is able to detect this frequency along the length of the structure. The success of RFD in tracing underground utilities is based on the composition of the structure (metal or plastic) and the ability to accurately position the transmitter unit so that it can be attached to, or placed directly over the structure. RFD should only be used to verify the location of utility mark-outs, and not as the primary method of utility identification.

##### **Soil Vacuum Excavation**

This method uses nondestructive vacuum excavation methods to create a visual test hole allowing the confirmation of buried utilities. This method is very accurate and relatively fast and can be performed prior to or during the drilling program. The limiting factors for this method are cost and availability. As with specialty drilling methods, a limited number of firms have the equipment to perform vacuum excavation.

The location of the structures to be cleared relative to the source and depth of impacted soil or groundwater is considered. If the zone to be cleared is known not to contain hazardous vapors or petroleum hydrocarbons via previous testing, continuous air monitoring is implemented using a lower explosive level (LEL)/O2 meter and photoionization detector (PID) or flame ionization detector (FID) to the depth of the boring. Also consistent with the site health and safety plan (HASP), air monitoring should be conducted continuously with the LEL/O2 meter during any activity if flammable or explosive vapors are suspected to be present. Prior to any subsurface investigation activities, air monitoring should be conducted to establish background levels for total organic vapors using a PID or FID. All work activity must STOP where tests indicate the concentration of flammable vapors exceeds 10% of the LEL, and the source of vapors must be investigated.

Vacuum-assisted soil excavation utility clearance will not be used in areas know to contain hazardous vapors or petroleum hydrocarbons unless the equipment to be used is suitable for flammable/explosive atmospheres. There is a significantly increased risk of explosion if these

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materials are encountered while performing this type of utility clearance. Cautions will be performed, as identified below.


#### **Cautions**

Many vacuum systems that are commonly used for utility clearance are considered unsuitable for use for environmental investigation sites. Most vacuum units are "Not for use with Hydrocarbons, Explosives, Corrosive or Toxic Material," and are "Not Intrinsically Safe."

Given that many units and associated tanking are not explosion-proof, the following steps will be considered prior to using vacuum- assisted utility clearance units where soils could be impacted with petroleum hydrocarbons or flammable vapors.

1. Request from the manufacturer and/or the contractor doing the work to supply manufacturers' documentation and specifications for use of the unit at environmental sites.
2. Request documentation that the unit is intrinsically safe and may be used in areas where petroleum hydrocarbon may be present.
3. Obtain the procedures for grounding portable units to discharge potential static electricity during operation.
4. If none of the above are available, then hand auger instead and do not use vacuum-assisted methods.



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### **Exhibit 5 - Emergency Action Plan Guidelines**

When work activities result in the contact or compromise of a utility line, an appropriate response is critical to prevent injury, death or significant property damage. Although circumstances and response vary depending on site specific conditions, the following guidelines provide information that is factored into emergency action planning associated with utility damage. In any event, emergency planning is coordinated with the entity that owns the utility and the client prior to the start of work. This planning and the appropriate response actions are documented in the project health and safety plan and reviewed with all field staff.

#### **Contact with Above or Underground Electric**


Contact with above ground or underground electric lines may result in the equipment being energized. Field personnel do not assume rubber tires on equipment are insulating the equipment from the ground. For underground electric strikes, contact with the line may not be immediately noticeable but indications of a strike include: power outage, smoke, explosion, popping noises, or arching electricity. If contact with an electric line is made or is suspected, the following guidelines are followed:

- Under most circumstances, the equipment operator or any worker on a seat of the equipment should stay on the equipment. These workers should not touch anything, especially metal, on the equipment.
- If it is determined that the equipment should be vacated due to a life threatening circumstance, the worker(s) should jump clear as far as possible from the equipment. When jumping keep both feet together and hop away to a safe distance after landing on the ground. Do not use hand holds or touch any part of the equipment when preparing to jump off.
- Workers on the ground should move away from the equipment.
- Keep others away from the equipment and the area.
- If anyone is injured and in contact with the line or equipment, any attempted rescue should be performed with extreme caution. Only use long, dry, clean, unpainted pieces of wood or fiberglass pole or long dry, clean rope to retrieve the victim. Perform first aid/CPR only after the victim is sufficiently clear from the electrical hazard.
- Notify the electric utility or the client as appropriate for the site. Call 911 or the client's emergency response phone number, as appropriate, for any serious injury or any situation that may result in fire or other hazard that could produce injury or property damage.

#### **Natural Gas**

If a natural gas line of any size is compromised, immediately:

- Shut off the equipment and remove any other ignition sources.
- Evacuate the area as quickly as possible.

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- DO NOT attempt to turn off any gas valves.
- Call 911 or the designated client emergency response number as appropriate.
- Call the gas utility, if site response is not controlled by the client.
- Do not return to the area until permitted by the utility or by the approved client emergency response personnel, as appropriate.

#### **Water Lines (all types)**


Compromised water lines may rapidly become a significant hazard especially if the line is under considerable pressure. Ruptured pressurized water lines may undermine and wash out unconsolidated materials beneath equipment or structures causing them to become unstable. If a pressurized water line is ruptured, the following guidelines should be followed:

- Promptly shut off all equipment.
- Lower masts or other high extension components of the equipment.
- Evacuate area and call the water utility or client emergency response number, as appropriate.
- Turn off the water if the valve location is known and on the site property.
- If potable water lines have been ruptured, attempt to divert any flow away from structures prone to being flooded. Use caution and keep a safe distance from the line break since the ground surface may be compromised.
- For raw process water or other water of unknown quality, do not attempt to divert or contain. Avoid skin contact or accidental ingestion of any water.
- When returning to the area of the break, survey the area for signs of compromised land surface (cracks in asphalt or concrete, depressions in ground, observations of undercutting, etc.) and avoid moving any equipment until these conditions are repaired or resolved.

#### **Sewers (all types)**

Use the same general guidelines for water lines when responding to compromised sewers. If a sanitary sewer is compromised additional guidelines should be followed to avoid contracting any bacterial illnesses. These include:

- Promptly evacuate the area.
- Avoid contact with any sewage material.
- If contaminated, promptly wash with soap (antimicrobial) and water and promptly change impacted clothing.

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- If sewage is accidentally ingested or infiltrates any breach of the skin or enters the eyes, seek medical attention as a precautionary measure.
- Decontaminate equipment with commercially available disinfectant solutions or a 10% chlorine bleach solution.

#### **Communication Lines**

Contact and compromise of communication lines are generally considered more of a financial concern than a concern associated with injury. However, eye damage may occur if looking into the ends of a cut fiber optic line. Do not look into the ends of fiber optic lines or other communication lines of unknown type. Promptly contact the communication company owning the line.


#### **Product Lines and Underground Storage Tanks (all types)**

Compromise of a product line or underground storage tank (UST) requires immediate action to mitigate impact to the environment. For gasoline stations and similar facilities the following guidelines should be followed during a line or UST breach:

- Immediately shut down equipment and turn off the emergency shutoff switch for the facility dispensers.
- If there are no injuries, attempt to contain any flowing product using absorbent materials and/or by physically pumping or bailing product out of the breached area.
- If product is flowing on the surface away from the break area, attempt to protect downgradient storm drains, sewer drains, and surface water features from impact of the petroleum product using any readily available materials.
- If the bottom of a UST has been breached, immediately contact a pump truck to remove product from the affected UST.
- For releases involving diesel fuel, care will be taken to avoid any situation where diesel may be injected into the body from impalement by coated nails, wood splinters, etc. If diesel is injected into the body, seek prompt medical attention, even if no apparent symptoms of a problem exist.
- Clear area and arrange for prompt repair.

For industrial sites with lines or USTs containing multiple products with varying hazards, similar guidelines may be followed as above if the material encountered is known and workers have a fundamental understanding of the hazards associated with the material. Upon discovery of a line or UST breach due to work activities at these sites:

- Immediately stop work and notify the client representative or call the client designated emergency number. For abandoned sites call 911.

 <b>ARCADIS</b> <small>infrastructure, environment, resources</small>	<u>ARCADIS HS Procedure Name</u> Utility Location Policy and Procedure	<u>Revision Number</u> 05
<u>Implementation Date</u> 13 December 2006	<u>ARCADIS HS Procedure No.</u> ARCHSFS019	<u>Revision Date</u> 22 February 2008
<u>Author</u> Michael Thomas	Page E12 of E12	<u>Approver</u> Mija Coppola

- If the material is not known, promptly evacuate the area and let HAZMAT teams deal with the release.

ARCADIS

**Appendix I**

Lead Policy and Procedure

## **Lead – Health and Safety Policy and Procedures**

ARCADIS SOP: ARC HSIH010

Revision #2

Revision Date: 6 September 2007

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# ARCADIS

SOP: ARC HSIH010 Lead – Health and Safety Policy and Procedures  
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## 7.0 Records

2



**Lead – Health and Safety Policy and Procedures****Approval Signatures**

Approved by:

*Michael A. Thomas*

Michael A. Thomas, CIH, Corporate HS Director

Approved by:

*Patricia A. Vollertsen*

Revision Date	Revision Number	Reason for change
26 March 2007	01	Original document
6 September 2007	02	Changing over to new template format

Corporate HS Manager

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## 1.0 Policy

ARCADIS understands the hazards of personal exposure to lead. Based on this understanding, ARCADIS will implement the appropriate controls to minimize or eliminate the hazards of lead. These controls will focus first on engineering controls to mitigate lead hazards where appropriate and practical. Administrative controls may also be implemented as appropriate and practical. Where it is not appropriate or practical to implement engineering and administrative controls, personal protective equipment (PPE) will be implemented to control lead hazards below known occupational exposure limits.

## 2.0 Purpose and Scope

### 2.1 Purpose

2.1.1 **Exposure to Lead** - This policy and associated procedures provides information to protect ARCADIS employees, subcontractors, and other effected personnel from exposures to lead while conducting work on ARCADIS projects.

2.1.2 **OSHA Standards** – This policy meets the requirements of the U.S. Occupational Safety and Health Administration (OSHA) regulations including Title 29 Code of Federal Regulations (CFR) Part 1910.1025 and Part 1926.62

### 2.2 Scope

This policy and the associated procedures apply to all projects where lead is known or thought to be present, and where ARCADIS employees, subcontractors and other effected personnel are or could be exposed to lead above the Action Level.

## 3.0 Definitions

**Action Level** is the airborne concentration established by OSHA that triggers certain regulatory requirements.

**Authorized person** means any person authorized by ARCADIS and required by work duties to be present in lead regulated areas.

**Lead** is a naturally occurring bluish-gray metal found in small amounts in the earth's crust. Lead can be found in all parts of our environment. Much of it comes from human activities including burning fossil fuels, mining, and manufacturing.

Lead has many different uses. It is used in the production of batteries, ammunition, metal products (solder and pipes), and devices to shield X-rays. Because of health concerns, lead

from gasoline, paints and ceramic products, caulking, and pipe solder has been dramatically reduced in recent years.

Lead is encountered on ARCADIS projects as a contaminant in soils, ground and surface water, sediments, and other environmental media. It can also be encountered through the air where dusts containing lead are present. Personnel may also encounter lead in other forms at certain client facilities at which ARCADIS works. It can be encountered at mining and smelting operations, battery manufacturing facilities, chemical production facilities where metal coatings or plastics are manufactured and other types of industrial sites. In addition, other activities that may expose ARCADIS staff to lead include:

- Demolition or salvage of structures where lead or materials containing lead are present;
- Removal or encapsulation of materials containing lead;
- New construction, alteration, repair, or renovation of structures, substrates, or portions thereof, that contain lead, or materials containing lead;
- Installation of products containing lead;
- Lead contamination/emergency cleanup;
- Transportation, disposal, storage, or containment of lead or materials containing lead on the site or location at which construction activities are performed, and
- Maintenance operations associated with the construction activities described in this paragraph.

**High-efficiency particulate air [HEPA] filter** means a filter capable of trapping and retaining at least 99.97 percent of mono-dispersed particles of 0.3 micrometers in diameter.

**Permissible Exposure Limit (PEL)** is an average airborne concentration regulatory limit established by OSHA above which requires control to protect people from adverse health effects.

**Short Term Exposure Limit (STEL)** is a PEL or TLV established as a limit of exposure measured over a designated period of time less than 8 hours.

**Threshold Limit Value** is a recommended average airborne concentration limit established by ACGIH. The TLVs are reviewed and updated as appropriate annually.

**Time Weighted Average (TWA)** is a measurement of airborne exposure to a chemical compound measured and averaged over a designated period of time for comparison to an STEL or an 8-hour PEL or TLV.

#### **4.0 Responsibilities**

**4.1 Project Managers** are responsible, as part of the project hazard assessment, for determining if lead is or is potentially present on a project site. In addition, the project manager is responsible for determining client requirements with respect to the control of lead hazards. *Project Managers notify health and safety staff when working on sites containing lead. Project Managers are also responsible for ensuring that project staff has the appropriate and applicable training for lead prior to those staff beginning work.*

**4.2 Corporate Health and Safety** is responsible for keeping this policy and procedure up-to-date with current regulatory requirements and best practices. In addition, Corporate Health and Safety oversees the medical surveillance program for lead, as applicable and provides a lead training package to for presentation to appropriate staff.

**4.3 Project Health and Safety Staff** including designated Writers and Reviewers of Project Health and Safety Plans (HASPs) are responsible for developing control processes and techniques on specific projects based on the levels of lead expected to be encountered on project facilities.

**4.4 Regional and Division HS Staff** are responsible for supporting and assisting the project and task managers, and the project HS staff in the implementation of this policy and the associated procedures.

**4.5 Project Personnel** are responsible for completing lead training as required by this policy and procedure, and for following all hazard control processes designated by the Project Manager, Project Health and Safety Staff, and the project HASP. If project personnel believe that lead is present that was not previously identified or is at levels that are higher than expected, they should stop work and notify project health and safety staff or the project manager immediately and not proceed until authorized.

## 5.0 Procedure

### 5.1 Procedure

#### 5.1.1 Lead Hazards

The health effects of lead are based on the type of exposure encountered by workers.

The primary route of exposure to lead in the work place is through inhalation of airborne lead. However, oral ingestion may represent a major route of exposure in contaminated workplaces. Most exposures occur with inorganic lead. Organic (tetraethyl and tetramethyl) lead, which was added to gasoline until the late 1970s, is not commonly encountered. Organic forms may be absorbed through the skin, while inorganic forms cannot.

Inorganic lead is not metabolized, but is directly absorbed, distributed and excreted. The rate depends on its chemical and physical form and on the physiological characteristics of the exposed person (e.g. nutritional status and age). Once in the blood, lead is distributed primarily among three compartments – blood, soft tissue (kidney, bone marrow, liver, and brain), and mineralizing tissue (bones and teeth). Absorption via the gastro-intestinal (GI) track following ingestion is highly dependent upon presence of levels of calcium, iron, fats, and proteins.

#### 5.1.2 Exposure Limits and Regulated Areas

The following personal exposure limits are established for lead by inhalation:

- OSHA ACTION LEVEL – 30 micrograms per cubic meter of air ( $\mu\text{g}/\text{m}^3$ ) lead in air 8-hour time weighted average (TWA).
- OSHA PERMISSIBLE EXPOSURE LEVELS (PELs)
  - TWA - 50  $\mu\text{g}/\text{m}^3$  lead in air averaged over an 8 hour period.
- ACGIH THRESHOLD LIMIT VALUES (TLVs)
  - TWA – 50  $\mu\text{g}/\text{m}^3$  lead in air averaged over an 8 hour period.
- Personal exposure is the concentration of lead to which a person would be exposed if that person were not wearing respiratory protection. Personal exposures shall be measured over the exposure period in the breathing zone of the employee. Personal exposures should not be determined by area sampling.

- REGULATED AREA

An area where the lead exposure does or can be expected to exceed the PEL. Since it may be difficult to determine the exposure time for employees working in areas with concentrations that exceed PEL values, the facility/location may wish to regulate any area that exceeds the 8-hour TWA PEL.. Only Authorized Persons are permitted to enter regulated areas.

#### 5.1.3 Actions for Employee Exposures Greater Than or Equal to the Action Level but Less Than the PELs

- Training – Annual lead training is required.
- Medical Surveillance – Initial and annual medical exams (see below) are required if employee personal exposures do or can be reasonably expected to exceed the Action Level on at least 30 calendar days during the coming year.
- Periodic Monitoring – shall be conducted at least annually until at least two consecutive exposure determinations (no less than 7 days apart) indicate the exposure is below the Action Level.

#### 5.1.4 Actions for Employee Exposures Greater Than PELs

- Respiratory Protection – a minimum of full face air-purifying respirators equipped with HEPA filters shall be used in all regulated areas.
- Training – Annual lead training is required.
- Medical Surveillance – Initial and annual medical exams (see below) are required if employee personal exposures do or can be reasonably expected to exceed the PEL on a least 10 calendar days during the coming year.
- Written Program – A written program to reduce personal exposure is required detailing the methods to be used to reduce exposures below the PEL. These written programs will be in the form of the project HASP based on project-specific and client requirements. The HASP will indicate the schedule for the implementation of the any lead-related hazard control processes or methods. The HASP is reviewed periodically but at least annually per the ARCADIS SOP ARC HSFS010 – Health and Safety Plans. All project personnel have access to the project HASP at all times.
- Periodic Monitoring – at least every 6 months until at least two consecutive exposure determinations (no less than 7 days apart) indicate the exposure is below the PEL; then

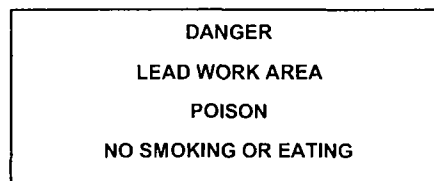
annually until at least two consecutive exposure determinations (no less than 7 days apart) indicate the exposure is below the PEL Action Level.

#### 5.1.5 Exposure Monitoring

- Representative personal exposure monitoring is required for each type of operation involving the handling of or potential exposure to lead.
- Initial monitoring can be omitted if there is documented data or industrial hygiene calculations to demonstrate that exposures are below the action level.
- Personal exposure monitoring shall utilize standard industrial hygiene sampling techniques and recordkeeping.
  - Employees who have been monitored for lead exposure shall be notified of the monitoring results within 15 working days of receipt of these results . If the PEL is exceeded, the notification must indicate the follow-up plans or corrective actions to be taken to reduce exposures to below the PEL.
- Personal TWA monitoring can be used for extended tasks, such as soil and sediment sampling, working on mine sites where lead is present, where clients require monitoring, etc.
- Area sampling can be used to determine regulated areas;
- Periodic Monitoring is required if exposures exceed the Action Level or PELs.

#### 5.1.6 Requirements for Regulated Areas

- Posting – Regulated areas shall be indicated such as by barricades, barricade tape, painted demarcations, or other devices.
- A sign shall be posted at the access to the regulated area with the warning:



[Minimum lettering height: DANGER LEAD WORK AREA 4"; others 3"]

- Respiratory Protection – Respirators shall be worn by all personnel when in a regulated area, regardless of the time period or over-all personal exposure measurement.
- Labeling:
  - In addition to appropriate Hazard Communication labeling, containers or equipment containing lead or lead compounds must also be labeled as such:

**CAUTION**

**ITEMS CONTAMINATED WITH LEAD**

**DO NOT REMOVE DUST BY BLOWING**  
**OR SHAKING**

**DISPOSE OF LEAD CONTAMINATED**  
**MATERIALS AND WASH WATER IN**  
**ACCORDANCE WITH LOCAL, STATE**  
**(PROVINCIAL) OR FEDERAL**  
**REGULATIONS**

- Eating, drinking, smoking, chewing any item, or applying cosmetics is strictly prohibited in a lead regulated area.

#### 5.1.7 Exposure Reduction

- Written Program:
  - The Project Manager and the Project Health and Safety Staff will develop a written program and make a determination as to the initial exposure levels to be included in the project HASP for exposure reduction if there is a determination that employee exposures may exceed the OSHA Action Level. The HASP will be reviewed at least annually. The program must include:
    - The locations and operations of potential lead exposure
    - Means to achieve compliance
    - Available air monitoring data or industrial hygiene estimates of airborne concentrations
    - Schedule for implementing control procedures
    - Exposure control processes
    - Medical surveillance requirements
    - Training requirements
    - Emergency response
  - The written program must list the corrective actions that will be taken to reduce employee exposure to at or below the OSHA Action Level:
    - identify regulated areas/tasks and the operations where lead may be encountered;



- the specific means to achieve compliance with OSHA, client, and other applicable requirements;
  - engineering controls;
  - revised work practices;
  - respiratory protection and protective clothing; and
  - schedule of development and implementation.
- Spills and Emergencies:

An emergency is any occurrence which may result in an unexpected significant release of lead or lead-containing compounds that may result in a significant inhalation. After an emergency, appropriate monitoring must be conducted to assure the ambient lead levels are back to normal; and conduct appropriate medical surveillance for affected employee(s).

- Respiratory Protection and Personal Protective Equipment:
  - Respirators shall be worn, maintained and managed in accordance with the OSHA standard, 29 CFR 1910.134 and ARCADIS SOP ARC HSGE017 – Respiratory Protection. In addition, any client requirements on project sites will be followed.
  - Respiratory protection will be worn in all areas as determined in the project HASP and per client requirements. Respirators will be at a minimum, full-face air purifying respirators equipped with HEPA filters.
  - Protective clothing will be worn per the requirements of the client or the project HASP and will include at a minimum at or above the OSHA Action Level:
    - Coveralls
    - Gloves
    - Hood
    - Boots and boot covers
    - Face shield (depending on operation)
    - Goggles

- Ventilation Systems:

Where appropriate, ventilation systems will be utilized to control the level of airborne lead per the client and HASP requirements. These ventilation systems will be equipped with HEPA filtration and be maintained to ensure effective collection of the lead particulate. Personnel who maintain these systems and change the filters will be appropriately protected per this policy and procedure to minimize exposure.

- Personal Hygiene:

Where lead is present at any level, project personnel handling such media containing lead will wear gloves to minimize exposure of lead to the skin that can then be transferred to the mouth. In all areas where lead is present, personnel will dutifully wash their hands and face before leaving the area to eat, drink, smoke, chew or apply cosmetics. Decontamination and changing facilities will be provided as necessary. In situations as indicated in the project HASP, PPE will be worn to protect the skin from exposure. However, even where PPE is worn, hand and face washing is required.

#### 5.1.8 Medical Surveillance

- Initial medical surveillance is required:
  - If employee personal exposures are reasonably expected to exceed the Action Level on at least 30 calendar days per year; or
  - If employee personal exposures are reasonably expected to exceed the PEL on a least 10 calendar days per year.
- Periodic exams are required on an annual basis for employees who continue to meet the criteria listed above. Annual exams may be discontinued after the exam conducted the year after personal exposures fall below the limits stated above in this section.
- The specific medical exam requirements are explained in detail in ARCADIS SOP ARC HSGE010 - Medical Surveillance. In addition, ARCADIS will work with WorkCare to ensure the proper medical surveillance, testing and notification is completed related to exposure to lead. This includes timing of sampling (e.g., at least every 6 months to each covered employee; at least every two months for each employee whose last blood sampling and analysis indicated a blood lead level at or above 40 ug/100 g of whole blood; and at least monthly during the removal period), treatment if levels are elevated (e.g., temporary removal from the site), and employee notification (i.e., within 5 days of levels are not acceptable).
- The physician must be supplied a copy of the OSHA lead regulation 29 CFR 1910.1025 and a description of the employee's lead exposure.
- For employees exposed to lead from an emergency, ARCADIS will immediately call WorkCare and follow all instructions for treatment and testing

#### 5.1.9 Training

- Initial lead training is required for all employees assigned to a work area suspected or known to contain lead. This training can be accomplished at the project orientation prior to the initiation of site work.

- Annual lead training is required at a minimum for all employees actually or potentially exposed to greater than the Action Level.
- Initial and annual training shall consist of:
  - The operations that involve lead exposure.
  - The methods/observations that can be used to detect the presence or release of lead
  - The physical and health hazards of lead.
  - Methods used to protect against the hazards of lead including PPE and respiratory protection.
  - The proper use of personal protective equipment in emergency situations.
  - The meaning of a regulated area and how such are demarcated.
  - A review of the applicable standard and where copies can be found.
  - An explanation of the medical surveillance program and an employee's right to access medical and exposure records.

## 6.0 References

- OSHA 29 CFR 1910.1025 – Lead
- OSHA 29 CFR 1926.62 – Lead
- ACGIH 2006 TLVs and BEIs – Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices
- ARCADIS Medical Surveillance SOP – ARC HSGE006
- ARCADIS Respiratory Protection SOP – ARC HSGE017

## 7.0 Records

- All exposure, medical, and training records shall be kept for 40 years or at least 20 years past the last date of employment.
- All exposure and medical records shall be made available to appropriate regulatory agencies upon written request.
- Employees who have been monitored for lead exposure shall be notified of the monitoring results within 15 working days of receipt of these results; a written request is not required

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## **Appendix B**

Standard Operating Procedures

FIELD PORTABLE X-RAY FLUORESCENCE SPECTROMETRY FOR THE  
DETERMINATION OF ELEMENTAL CONCENTRATIONS IN SOIL AND SEDIMENT

SW-846 is not intended to be an analytical training manual. Therefore, method procedures are written based on the assumption that they will be performed by analysts who are formally trained in at least the basic principles of chemical analysis and in the use of the subject technology.

In addition, SW-846 methods, with the exception of required method use for the analysis of method-defined parameters, are intended to be guidance methods which contain general information on how to perform an analytical procedure or technique which a laboratory can use as a basic starting point for generating its own detailed Standard Operating Procedure (SOP), either for its own general use or for a specific project application. The performance data included in this method are for guidance purposes only, and are not intended to be and must not be used as absolute QC acceptance criteria for purposes of laboratory accreditation.

## 1.0 SCOPE AND APPLICATION

1.1 This method is applicable to the in situ and intrusive analysis of the 26 analytes listed below for soil and sediment samples. Some common elements are not listed in this method because they are considered "light" elements that cannot be detected by field portable x-ray fluorescence (FPXRF). These light elements are: lithium, beryllium, sodium, magnesium, aluminum, silicon, and phosphorus. Most of the analytes listed below are of environmental concern, while a few others have interference effects or change the elemental composition of the matrix, affecting quantitation of the analytes of interest. Generally elements of atomic number 16 or greater can be detected and quantitated by FPXRF. The following RCRA analytes have been determined by this method:

Analytes	CAS Registry No.
Antimony (Sb)	7440-36-0
Arsenic (As)	7440-38-0
Barium (Ba)	7440-39-3
Cadmium (Cd)	7440-43-9
Chromium (Cr)	7440-47-3
Cobalt (Co)	7440-48-4
Copper (Cu)	7440-50-8
Lead (Pb)	7439-92-1
Mercury (Hg)	7439-97-6
Nickel (Ni)	7440-02-0
Selenium (Se)	7782-49-2
Silver (Ag)	7440-22-4
Thallium (Tl)	7440-28-0
Tin (Sn)	7440-31-5

Analytes	CAS Registry No.
Vanadium (V)	7440-62-2
Zinc (Zn)	7440-66-6

In addition, the following non-RCRA analytes have been determined by this method:

Analytes	CAS Registry No.
Calcium (Ca)	7440-70-2
Iron (Fe)	7439-89-6
Manganese (Mn)	7439-96-5
Molybdenum (Mo)	7439-93-7
Potassium (K)	7440-09-7
Rubidium (Rb)	7440-17-7
Strontium (Sr)	7440-24-6
Thorium (Th)	7440-29-1
Titanium (Ti)	7440-32-6
Zirconium (Zr)	7440-67-7

1.2 This method is a screening method to be used with confirmatory analysis using other techniques (e.g., flame atomic absorption spectrometry (FLAA), graphite furnace atomic absorption spectrometry (GFAA), inductively coupled plasma-atomic emission spectrometry, (ICP-AES), or inductively coupled plasma-mass spectrometry, (ICP-MS)). This method's main strength is that it is a rapid field screening procedure. The method's lower limits of detection are typically above the toxicity characteristic regulatory level for most RCRA analytes. However, when the obtainable values for precision, accuracy, and laboratory-established sensitivity of this method meet project-specific data quality objectives (DQOs), FPXRF is a fast, powerful, cost effective technology for site characterization.

1.3 The method sensitivity or lower limit of detection depends on several factors, including the analyte of interest, the type of detector used, the type of excitation source, the strength of the excitation source, count times used to irradiate the sample, physical matrix effects, chemical matrix effects, and interelement spectral interferences. Example lower limits of detection for analytes of interest in environmental applications are shown in Table 1. These limits apply to a clean spiked matrix of quartz sand (silicon dioxide) free of interelement spectral interferences using long (100 -600 second) count times. These sensitivity values are given for guidance only and may not always be achievable, since they will vary depending on the sample matrix, which instrument is used, and operating conditions. A discussion of performance-based sensitivity is presented in Sec. 9.6.

1.4 Analysts should consult the disclaimer statement at the front of the manual and the information in Chapter Two for guidance on the intended flexibility in the choice of methods, apparatus, materials, reagents, and supplies, and on the responsibilities of the analyst for demonstrating that the techniques employed are appropriate for the analytes of interest, in the matrix of interest, and at the levels of concern.

In addition, analysts and data users are advised that, except where explicitly specified in a regulation, the use of SW-846 methods is *not* mandatory in response to Federal testing requirements. The information contained in this method is provided by EPA as guidance to be used by the analyst and the regulated community in making judgments necessary to generate results that meet the data quality objectives for the intended application.

1.5 Use of this method is restricted to use by, or under supervision of, personnel appropriately experienced and trained in the use and operation of an XRF instrument. Each analyst must demonstrate the ability to generate acceptable results with this method.

## 2.0 SUMMARY OF METHOD

2.1 The FPXRF technologies described in this method use either sealed radioisotope sources or x-ray tubes to irradiate samples with x-rays. When a sample is irradiated with x-rays, the source x-rays may undergo either scattering or absorption by sample atoms. This latter process is known as the photoelectric effect. When an atom absorbs the source x-rays, the incident radiation dislodges electrons from the innermost shells of the atom, creating vacancies. The electron vacancies are filled by electrons cascading in from outer electron shells. Electrons in outer shells have higher energy states than inner shell electrons, and the outer shell electrons give off energy as they cascade down into the inner shell vacancies. This rearrangement of electrons results in emission of x-rays characteristic of the given atom. The emission of x-rays, in this manner, is termed x-ray fluorescence.

Three electron shells are generally involved in emission of x-rays during FPXRF analysis of environmental samples. The three electron shells include the K, L, and M shells. A typical emission pattern, also called an emission spectrum, for a given metal has multiple intensity peaks generated from the emission of K, L, or M shell electrons. The most commonly measured x-ray emissions are from the K and L shells; only metals with an atomic number greater than 57 have measurable M shell emissions.

Each characteristic x-ray line is defined with the letter K, L, or M, which signifies which shell had the original vacancy and by a subscript alpha ( $\alpha$ ), beta ( $\beta$ ), or gamma ( $\gamma$ ) etc., which indicates the higher shell from which electrons fell to fill the vacancy and produce the x-ray. For example, a  $K_\alpha$  line is produced by a vacancy in the K shell filled by an L shell electron, whereas a  $K_\beta$  line is produced by a vacancy in the K shell filled by an M shell electron. The  $K_\alpha$  transition is on average 6 to 7 times more probable than the  $K_\beta$  transition; therefore, the  $K_\alpha$  line is approximately 7 times more intense than the  $K_\beta$  line for a given element, making the  $K_\alpha$  line the choice for quantitation purposes.

The K lines for a given element are the most energetic lines and are the preferred lines for analysis. For a given atom, the x-rays emitted from L transitions are always less energetic than those emitted from K transitions. Unlike the K lines, the main L emission lines ( $L_\alpha$  and  $L_\beta$ ) for an element are of nearly equal intensity. The choice of one or the other depends on what interfering element lines might be present. The L emission lines are useful for analyses involving elements of atomic number (Z) 58 (cerium) through 92 (uranium).

An x-ray source can excite characteristic x-rays from an element only if the source energy is greater than the absorption edge energy for the particular line group of the element, that is, the K absorption edge, L absorption edge, or M absorption edge energy. The absorption edge energy is somewhat greater than the corresponding line energy. Actually, the K absorption edge energy is approximately the sum of the K, L, and M line energies of the particular element, and the L absorption edge energy is approximately the sum of the L and M line energies. FPXRF is more sensitive to an element with an absorption edge energy close to but less than



the excitation energy of the source. For example, when using a cadmium-109 source, which has an excitation energy of 22.1 kiloelectron volts (keV), FPXRF would exhibit better sensitivity for zirconium which has a K line energy of 15.77 keV than to chromium, which has a K line energy of 5.41 keV.

2.2 Under this method, inorganic analytes of interest are identified and quantitated using a field portable energy-dispersive x-ray fluorescence spectrometer. Radiation from one or more radioisotope sources or an electrically excited x-ray tube is used to generate characteristic x-ray emissions from elements in a sample. Up to three sources may be used to irradiate a sample. Each source emits a specific set of primary x-rays that excite a corresponding range of elements in a sample. When more than one source can excite the element of interest, the source is selected according to its excitation efficiency for the element of interest.

For measurement, the sample is positioned in front of the probe window. This can be done in two manners using FPXRF instruments, specifically, in situ or intrusive. If operated in the in situ mode, the probe window is placed in direct contact with the soil surface to be analyzed. When an FPXRF instrument is operated in the intrusive mode, a soil or sediment sample must be collected, prepared, and placed in a sample cup. The sample cup is then placed on top of the window inside a protective cover for analysis.

Sample analysis is then initiated by exposing the sample to primary radiation from the source. Fluorescent and backscattered x-rays from the sample enter through the detector window and are converted into electric pulses in the detector. The detector in FPXRF instruments is usually either a solid-state detector or a gas-filled proportional counter. Within the detector, energies of the characteristic x-rays are converted into a train of electric pulses, the amplitudes of which are linearly proportional to the energy of the x-rays. An electronic multichannel analyzer (MCA) measures the pulse amplitudes, which is the basis of qualitative x-ray analysis. The number of counts at a given energy per unit of time is representative of the element concentration in a sample and is the basis for quantitative analysis. Most FPXRF instruments are menu-driven from software built into the units or from personal computers (PC).

The measurement time of each source is user-selectable. Shorter source measurement times (30 seconds) are generally used for initial screening and hot spot delineation, and longer measurement times (up to 300 seconds) are typically used to meet higher precision and accuracy requirements.

FPXRF instruments can be calibrated using the following methods: internally using fundamental parameters determined by the manufacturer, empirically based on site-specific calibration standards (SSCS), or based on Compton peak ratios. The Compton peak is produced by backscattering of the source radiation. Some FPXRF instruments can be calibrated using multiple methods.

### 3.0 DEFINITIONS

- 3.1 FPXRF -- Field portable x-ray fluorescence.
- 3.2 MCA -- Multichannel analyzer for measuring pulse amplitude.
- 3.3 SSCS -- Site-specific calibration standards.
- 3.4 FP -- Fundamental parameter.
- 3.5 ROI -- Region of interest.

3.6 SRM -- Standard reference material; a standard containing certified amounts of metals in soil or sediment.

3.7 eV -- Electron volt; a unit of energy equivalent to the amount of energy gained by an electron passing through a potential difference of one volt.

3.8 Refer to Chapter One, Chapter Three, and the manufacturer's instructions for other definitions that may be relevant to this procedure.

#### 4.0 INTERFERENCES

4.1 The total method error for FPXRF analysis is defined as the square root of the sum of squares of both instrument precision and user- or application-related error. Generally, instrument precision is the least significant source of error in FPXRF analysis. User- or application-related error is generally more significant and varies with each site and method used. Some sources of interference can be minimized or controlled by the instrument operator, but others cannot. Common sources of user- or application-related error are discussed below.

4.2 Physical matrix effects result from variations in the physical character of the sample. These variations may include such parameters as particle size, uniformity, homogeneity, and surface condition. For example, if any analyte exists in the form of very fine particles in a coarser-grained matrix, the analyte's concentration measured by the FPXRF will vary depending on how fine particles are distributed within the coarser-grained matrix. If the fine particles "settle" to the bottom of the sample cup (i.e., against the cup window), the analyte concentration measurement will be higher than if the fine particles are not mixed in well and stay on top of the coarser-grained particles in the sample cup. One way to reduce such error is to grind and sieve all soil samples to a uniform particle size thus reducing sample-to-sample particle size variability. Homogeneity is always a concern when dealing with soil samples. Every effort should be made to thoroughly mix and homogenize soil samples before analysis. Field studies have shown heterogeneity of the sample generally has the largest impact on comparability with confirmatory samples.

4.3 Moisture content may affect the accuracy of analysis of soil and sediment sample analyses. When the moisture content is between 5 and 20 percent, the overall error from moisture may be minimal. However, moisture content may be a major source of error when analyzing samples of surface soil or sediment that are saturated with water. This error can be minimized by drying the samples in a convection or toaster oven. Microwave drying is not recommended because field studies have shown that microwave drying can increase variability between FPXRF data and confirmatory analysis and because metal fragments in the sample can cause arcing to occur in a microwave.

4.4 Inconsistent positioning of samples in front of the probe window is a potential source of error because the x-ray signal decreases as the distance from the radioactive source increases. This error is minimized by maintaining the same distance between the window and each sample. For the best results, the window of the probe should be in direct contact with the sample, which means that the sample should be flat and smooth to provide a good contact surface.

4.5 Chemical matrix effects result from differences in the concentrations of interfering elements. These effects occur as either spectral interferences (peak overlaps) or as x-ray absorption and enhancement phenomena. Both effects are common in soils contaminated with heavy metals. As examples of absorption and enhancement effects; iron (Fe) tends to absorb copper (Cu) x-rays, reducing the intensity of the Cu measured by the detector, while chromium (Cr) will be enhanced at the expense of Fe because the absorption edge of Cr is slightly lower in energy than the fluorescent peak of iron. The effects can be corrected mathematically through the use of fundamental parameter (FP) coefficients. The effects also can be compensated for using SSCS, which contain all the elements present on site that can interfere with one another.

4.6 When present in a sample, certain x-ray lines from different elements can be very close in energy and, therefore, can cause interference by producing a severely overlapped spectrum. The degree to which a detector can resolve the two different peaks depends on the energy resolution of the detector. If the energy difference between the two peaks in electron volts is less than the resolution of the detector in electron volts, then the detector will not be able to fully resolve the peaks.

The most common spectrum overlaps involve the  $K_{\beta}$  line of element Z-1 with the  $K_{\alpha}$  line of element Z. This is called the  $K_{\alpha}/K_{\beta}$  interference. Because the  $K_{\alpha}:K_{\beta}$  intensity ratio for a given element usually is about 7:1, the interfering element, Z-1, must be present at large concentrations to cause a problem. Two examples of this type of spectral interference involve the presence of large concentrations of vanadium (V) when attempting to measure Cr or the presence of large concentrations of Fe when attempting to measure cobalt (Co). The V  $K_{\alpha}$  and  $K_{\beta}$  energies are 4.95 and 5.43 keV, respectively, and the Cr  $K_{\alpha}$  energy is 5.41 keV. The Fe  $K_{\alpha}$  and  $K_{\beta}$  energies are 6.40 and 7.06 keV, respectively, and the Co  $K_{\alpha}$  energy is 6.92 keV. The difference between the V  $K_{\beta}$  and Cr  $K_{\alpha}$  energies is 20 eV, and the difference between the Fe  $K_{\beta}$  and the Co  $K_{\alpha}$  energies is 140 eV. The resolution of the highest-resolution detectors in FPXRF instruments is 170 eV. Therefore, large amounts of V and Fe will interfere with quantitation of Cr or Co, respectively. The presence of Fe is a frequent problem because it is often found in soils at tens of thousands of parts per million (ppm).

4.7 Other interferences can arise from K/L, K/M, and L/M line overlaps, although these overlaps are less common. Examples of such overlap involve arsenic (As)  $K_{\alpha}$ /lead (Pb)  $L_{\alpha}$  and sulfur (S)  $K_{\alpha}$ /Pb  $M_{\alpha}$ . In the As/Pb case, Pb can be measured from the Pb  $L_{\beta}$  line, and As can be measured from either the As  $K_{\alpha}$  or the As  $K_{\beta}$  line; in this way the interference can be corrected. If the As  $K_{\beta}$  line is used, sensitivity will be decreased by a factor of two to five times because it is a less intense line than the As  $K_{\alpha}$  line. If the As  $K_{\alpha}$  line is used in the presence of Pb, mathematical corrections within the instrument software can be used to subtract out the Pb interference. However, because of the limits of mathematical corrections, As concentrations cannot be efficiently calculated for samples with Pb:As ratios of 10:1 or more. This high ratio of Pb to As may result in reporting of a "nondetect" or a "less than" value (e.g., <300 ppm) for As, regardless of the actual concentration present.

No instrument can fully compensate for this interference. It is important for an operator to understand this limitation of FPXRF instruments and consult with the manufacturer of the FPXRF instrument to evaluate options to minimize this limitation. The operator's decision will be based on action levels for metals in soil established for the site, matrix effects, capabilities of the instrument, data quality objectives, and the ratio of lead to arsenic known to be present at the site. If a site is encountered that contains lead at concentrations greater than ten times the concentration of arsenic it is advisable that all critical soil samples be sent off site for confirmatory analysis using other techniques (e.g., flame atomic absorption spectrometry (FLAA), graphite furnace atomic absorption spectrometry (GFAA), inductively coupled plasma-

atomic emission spectrometry, (ICP-AES), or inductively coupled plasma-mass spectrometry, (ICP-MS)).

4.8 If SSCS are used to calibrate an FPXRF instrument, the samples collected must be representative of the site under investigation. Representative soil sampling ensures that a sample or group of samples accurately reflects the concentrations of the contaminants of concern at a given time and location. Analytical results for representative samples reflect variations in the presence and concentration ranges of contaminants throughout a site. Variables affecting sample representativeness include differences in soil type, contaminant concentration variability, sample collection and preparation variability, and analytical variability, all of which should be minimized as much as possible.

4.9 Soil physical and chemical effects may be corrected using SSCS that have been analyzed by inductively coupled plasma (ICP) or atomic absorption (AA) methods. However, a major source of error can be introduced if these samples are not representative of the site or if the analytical error is large. Another concern is the type of digestion procedure used to prepare the soil samples for the reference analysis. Analytical results for the confirmatory method will vary depending on whether a partial digestion procedure, such as Method 3050, or a total digestion procedure, such as Method 3052, is used. It is known that depending on the nature of the soil or sediment, Method 3050 will achieve differing extraction efficiencies for different analytes of interest. The confirmatory method should meet the project-specific data quality objectives (DQOs).

XRF measures the total concentration of an element; therefore, to achieve the greatest comparability of this method with the reference method (reduced bias), a total digestion procedure should be used for sample preparation. However, in the study used to generate the performance data for this method (see Table 8), the confirmatory method used was Method 3050, and the FPXRF data compared very well with regression correlation coefficients ( $r$  often exceeding 0.95, except for barium and chromium). The critical factor is that the digestion procedure and analytical reference method used should meet the DQOs of the project and match the method used for confirmation analysis.

4.10 Ambient temperature changes can affect the gain of the amplifiers producing instrument drift. Gain or drift is primarily a function of the electronics (amplifier or preamplifier) and not the detector as most instrument detectors are cooled to a constant temperature. Most FPXRF instruments have a built-in automatic gain control. If the automatic gain control is allowed to make periodic adjustments, the instrument will compensate for the influence of temperature changes on its energy scale. If the FPXRF instrument has an automatic gain control function, the operator will not have to adjust the instrument's gain unless an error message appears. If an error message appears, the operator should follow the manufacturer's procedures for troubleshooting the problem. Often, this involves performing a new energy calibration. The performance of an energy calibration check to assess drift is a quality control measure discussed in Sec. 9.2.

If the operator is instructed by the manufacturer to manually conduct a gain check because of increasing or decreasing ambient temperature, it is standard to perform a gain check after every 10 to 20 sample measurements or once an hour whichever is more frequent. It is also suggested that a gain check be performed if the temperature fluctuates more than 10° F. The operator should follow the manufacturer's recommendations for gain check frequency.

## 5.0 SAFETY

5.1 This method does not address all safety issues associated with its use. The user is responsible for maintaining a safe work environment and a current awareness file of OSHA regulations regarding the safe handling of the chemicals listed in this method. A reference file of material safety data sheets (MSDSs) should be available to all personnel involved in these analyses.

NOTE: No MSDS applies directly to the radiation-producing instrument because that is covered under the Nuclear Regulatory Commission (NRC) or applicable state regulations.

5.2 Proper training for the safe operation of the instrument and radiation training should be completed by the analyst prior to analysis. Radiation safety for each specific instrument can be found in the operator's manual. Protective shielding should never be removed by the analyst or any personnel other than the manufacturer. The analyst should be aware of the local state and national regulations that pertain to the use of radiation-producing equipment and radioactive materials with which compliance is required. There should be a person appointed within the organization that is solely responsible for properly instructing all personnel, maintaining inspection records, and monitoring x-ray equipment at regular intervals.

Licenses for radioactive materials are of two types, specifically: (1) a general license which is usually initiated by the manufacturer for receiving, acquiring, owning, possessing, using, and transferring radioactive material incorporated in a device or equipment, and (2) a specific license which is issued to named persons for the operation of radioactive instruments as required by local, state, or federal agencies. A copy of the radioactive material license (for specific licenses only) and leak tests should be present with the instrument at all times and available to local and national authorities upon request.

X-ray tubes do not require radioactive material licenses or leak tests, but do require approvals and licenses which vary from state to state. In addition, fail-safe x-ray warning lights should be illuminated whenever an x-ray tube is energized. Provisions listed above concerning radiation safety regulations, shielding, training, and responsible personnel apply to x-ray tubes just as to radioactive sources. In addition, a log of the times and operating conditions should be kept whenever an x-ray tube is energized. An additional hazard present with x-ray tubes is the danger of electric shock from the high voltage supply, however, if the tube is properly positioned within the instrument, this is only a negligible risk. Any instrument (x-ray tube or radioisotope based) is capable of delivering an electric shock from the basic circuitry when the system is inappropriately opened.

5.3 Radiation monitoring equipment should be used with the handling and operation of the instrument. The operator and the surrounding environment should be monitored continually for analyst exposure to radiation. Thermal luminescent detectors (TLD) in the form of badges and rings are used to monitor operator radiation exposure. The TLDs or badges should be worn in the area of maximum exposure. The maximum permissible whole-body dose from occupational exposure is 5 Roentgen Equivalent Man (REM) per year. Possible exposure pathways for radiation to enter the body are ingestion, inhaling, and absorption. The best precaution to prevent radiation exposure is distance and shielding.

## 6.0 EQUIPMENT AND SUPPLIES

The mention of trade names or commercial products in this manual is for illustrative purposes only, and does not constitute an EPA endorsement or exclusive recommendation for

use. The products and instrument settings cited in SW-846 methods represent those products and settings used during method development or subsequently evaluated by the Agency. Glassware, reagents, supplies, equipment, and settings other than those listed in this manual may be employed provided that method performance appropriate for the intended application has been demonstrated and documented.

6.1 FPXRF spectrometer -- An FPXRF spectrometer consists of four major components: (1) a source that provides x-rays; (2) a sample presentation device; (3) a detector that converts x-ray-generated photons emitted from the sample into measurable electronic signals; and (4) a data processing unit that contains an emission or fluorescence energy analyzer, such as an MCA, that processes the signals into an x-ray energy spectrum from which elemental concentrations in the sample may be calculated, and a data display and storage system. These components and additional, optional items, are discussed below.

6.1.1 Excitation sources -- FPXRF instruments use either a sealed radioisotope source or an x-ray tube to provide the excitation source. Many FPXRF instruments use sealed radioisotope sources to produce x-rays in order to irradiate samples. The FPXRF instrument may contain between one and three radioisotope sources. Common radioisotope sources used for analysis for metals in soils are iron Fe-55 ( $^{55}\text{Fe}$ ), cadmium Cd-109 ( $^{109}\text{Cd}$ ), americium Am-241 ( $^{241}\text{Am}$ ), and curium Cm-244 ( $^{244}\text{Cm}$ ). These sources may be contained in a probe along with a window and the detector; the probe may be connected to a data reduction and handling system by means of a flexible cable. Alternatively, the sources, window, and detector may be included in the same unit as the data reduction and handling system.

The relative strength of the radioisotope sources is measured in units of millicuries (mCi). All other components of the FPXRF system being equal, the stronger the source, the greater the sensitivity and precision of a given instrument. Radioisotope sources undergo constant decay. In fact, it is this decay process that emits the primary x-rays used to excite samples for FPXRF analysis. The decay of radioisotopes is measured in "half-lives." The half-life of a radioisotope is defined as the length of time required to reduce the radioisotopes strength or activity by half. Developers of FPXRF technologies recommend source replacement at regular intervals based on the source's half-life. This is due to the ever increasing time required for the analysis rather than a decrease in instrument performance. The characteristic x-rays emitted from each of the different sources have energies capable of exciting a certain range of analytes in a sample. Table 2 summarizes the characteristics of four common radioisotope sources.

X-ray tubes have higher radiation output, no intrinsic lifetime limit, produce constant output over their lifetime, and do not have the disposal problems of radioactive sources but are just now appearing in FPXRF instruments. An electrically-excited x-ray tube operates by bombarding an anode with electrons accelerated by a high voltage. The electrons gain an energy in electron volts equal to the accelerating voltage and can excite atomic transitions in the anode, which then produces characteristic x-rays. These characteristic x-rays are emitted through a window which contains the vacuum necessary for the electron acceleration. An important difference between x-ray tubes and radioactive sources is that the electrons which bombard the anode also produce a continuum of x-rays across a broad range of energies in addition to the characteristic x-rays. This continuum is weak compared to the characteristic x-rays but can provide substantial excitation since it covers a broad energy range. It has the undesired property of producing background in the spectrum near the analyte x-ray lines when it is scattered by the sample. For this reason a filter is often used between the x-ray tube and the sample to suppress the continuum radiation while passing the characteristic x-rays from the anode. This filter is sometimes incorporated into the window of the x-ray tube. The choice of

accelerating voltage is governed both by the anode material, since the electrons must have sufficient energy to excite the anode, which requires a voltage greater than the absorption edge of the anode material and by the instrument's ability to cool the x-ray tube. The anode is most efficiently excited by voltages 2 to 2.5 times the edge energy (most x-rays per unit power to the tube), although voltages as low as 1.5 times the absorption edge energy will work. The characteristic x-rays emitted by the anode are capable of exciting a range of elements in the sample just as with a radioactive source. Table 3 gives the recommended operating voltages and the sample elements excited for some common anodes.

6.1.2 Sample presentation device -- FPXRF instruments can be operated in two modes: in situ and intrusive. If operated in the in situ mode, the probe window is placed in direct contact with the soil surface to be analyzed. When an FPXRF instrument is operated in the intrusive mode, a soil or sediment sample must be collected, prepared, and placed in a sample cup. For FPXRF instruments operated in the intrusive mode, the probe may be rotated so that the window faces either upward or downward. A protective sample cover is placed over the window, and the sample cup is placed on top of the window inside the protective sample cover for analysis.

6.1.3 Detectors -- The detectors in the FPXRF instruments can be either solid-state detectors or gas-filled, proportional counter detectors. Common solid-state detectors include mercuric iodide ( $\text{HgI}_2$ ), silicon pin diode and lithium-drifted silicon  $\text{Si}(\text{Li})$ . The  $\text{HgI}_2$  detector is operated at a moderately subambient temperature controlled by a low power thermoelectric cooler. The silicon pin diode detector also is cooled via the thermoelectric Peltier effect. The  $\text{Si}(\text{Li})$  detector must be cooled to at least  $-90^\circ\text{C}$  either with liquid nitrogen or by thermoelectric cooling via the Peltier effect. Instruments with a  $\text{Si}(\text{Li})$  detector have an internal liquid nitrogen dewar with a capacity of 0.5 to 1.0 L. Proportional counter detectors are rugged and lightweight, which are important features of a field portable detector. However, the resolution of a proportional counter detector is not as good as that of a solid-state detector. The energy resolution of a detector for characteristic x-rays is usually expressed in terms of full width at half-maximum (FWHM) height of the manganese  $K_\alpha$  peak at 5.89 keV. The typical resolutions of the above mentioned detectors are as follows:  $\text{HgI}_2$ -270 eV; silicon pin diode-250 eV;  $\text{Si}(\text{Li})$ -170 eV; and gas-filled, proportional counter-750 eV.

During operation of a solid-state detector, an x-ray photon strikes a biased, solid-state crystal and loses energy in the crystal by producing electron-hole pairs. The electric charge produced is collected and provides a current pulse that is directly proportional to the energy of the x-ray photon absorbed by the crystal of the detector. A gas-filled, proportional counter detector is an ionization chamber filled with a mixture of noble and other gases. An x-ray photon entering the chamber ionizes the gas atoms. The electric charge produced is collected and provides an electric signal that is directly proportional to the energy of the x-ray photon absorbed by the gas in the detector.

6.1.4 Data processing units -- The key component in the data processing unit of an FPXRF instrument is the MCA. The MCA receives pulses from the detector and sorts them by their amplitudes (energy level). The MCA counts pulses per second to determine the height of the peak in a spectrum, which is indicative of the target analyte's concentration. The spectrum of element peaks are built on the MCA. The MCAs in FPXRF instruments have from 256 to 2,048 channels. The concentrations of target analytes are usually shown in ppm on a liquid crystal display (LCD) in the instrument. FPXRF instruments can store both spectra and from 3,000 to 5,000 sets of numerical analytical results. Most FPXRF instruments are menu-driven from software built into the

units or from PCs. Once the data-storage memory of an FPXRF unit is full or at any other time, data can be downloaded by means of an RS-232 port and cable to a PC.

6.2 Spare battery and battery charger.

6.3 Polyethylene sample cups -- 31 to 40 mm in diameter with collar, or equivalent (appropriate for FPXRF instrument).

6.4 X-ray window film -- Mylar™, Kapton™, Spectrolene™, polypropylene, or equivalent; 2.5 to 6.0 µm thick.

6.5 Mortar and pestle -- Glass, agate, or aluminum oxide; for grinding soil and sediment samples.

6.6 Containers -- Glass or plastic to store samples.

6.7 Sieves -- 60-mesh (0.25 mm), stainless-steel, Nylon, or equivalent for preparing soil and sediment samples.

6.8 Trowels -- For smoothing soil surfaces and collecting soil samples.

6.9 Plastic bags -- Used for collection and homogenization of soil samples.

6.10 Drying oven -- Standard convection or toaster oven, for soil and sediment samples that require drying.

## 7.0 REAGENTS AND STANDARDS

7.1 Reagent grade chemicals must be used in all tests. Unless otherwise indicated, it is intended that all reagents conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available. Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

7.2 Pure element standards -- Each pure, single-element standard is intended to produce strong characteristic x-ray peaks of the element of interest only. Other elements present must not contribute to the fluorescence spectrum. A set of pure element standards for commonly sought analytes is supplied by the instrument manufacturer, if designated for the instrument; not all instruments require the pure element standards. The standards are used to set the region of interest (ROI) for each element. They also can be used as energy calibration and resolution check samples.

7.3 Site-specific calibration standards -- Instruments that employ fundamental parameters (FP) or similar mathematical models in minimizing matrix effects may not require SSCS. If the FP calibration model is to be optimized or if empirical calibration is necessary, then SSCSs must be collected, prepared, and analyzed.

7.3.1 The SSCS must be representative of the matrix to be analyzed by FPXRF. These samples must be well homogenized. A minimum of 10 samples spanning the concentration ranges of the analytes of interest and of the interfering elements must be obtained from the site. A sample size of 4 to 8 ounces is recommended, and standard glass sampling jars should be used.



7.3.2 Each sample should be oven-dried for 2 to 4 hr at a temperature of less than 150 °C. If mercury is to be analyzed, a separate sample portion should be dried at ambient temperature as heating may volatilize the mercury. When the sample is dry, all large, organic debris and nonrepresentative material, such as twigs, leaves, roots, insects, asphalt, and rock should be removed. The sample should be homogenized (see Sec. 7.3.3) and then a representative portion ground with a mortar and pestle or other mechanical means, prior to passing through a 60-mesh sieve. Only the coarse rock fraction should remain on the screen.

7.3.3 The sample should be homogenized by using a riffle splitter or by placing 150 to 200 g of the dried, sieved sample on a piece of kraft or butcher paper about 1.5 by 1.5 feet in size. Each corner of the paper should be lifted alternately, rolling the soil over on itself and toward the opposite corner. The soil should be rolled on itself 20 times. Approximately 5 g of the sample should then be removed and placed in a sample cup for FPXRF analysis. The rest of the prepared sample should be sent off site for ICP or AA analysis. The method use for confirmatory analysis should meet the data quality objectives of the project.

7.4 Blank samples -- The blank samples should be from a "clean" quartz or silicon dioxide matrix that is free of any analytes at concentrations above the established lower limit of detection. These samples are used to monitor for cross-contamination and laboratory-induced contaminants or interferences.

7.5 Standard reference materials -- Standard reference materials (SRMs) are standards containing certified amounts of metals in soil or sediment. These standards are used for accuracy and performance checks of FPXRF analyses. SRMs can be obtained from the National Institute of Standards and Technology (NIST), the U.S. Geological Survey (USGS), the Canadian National Research Council, and the national bureau of standards in foreign nations. Pertinent NIST SRMs for FPXRF analysis include 2704, Buffalo River Sediment; 2709, San Joaquin Soil; and 2710 and 2711, Montana Soil. These SRMs contain soil or sediment from actual sites that has been analyzed using independent inorganic analytical methods by many different laboratories. When these SRMs are unavailable, alternate standards may be used (e.g., NIST 2702).

## 8.0 SAMPLE COLLECTION, PRESERVATION, AND STORAGE

Sample handling and preservation procedures used in FPXRF analyses should follow the guidelines in Chapter Three, "Inorganic Analytes."

## 9.0 QUALITY CONTROL

9.1 Follow the manufacturer's instructions for the quality control procedures specific to use of the testing product. Refer to Chapter One for additional guidance on quality assurance (QA) and quality control (QC) protocols. Any effort involving the collection of analytical data should include development of a structured and systematic planning document, such as a Quality Assurance Project Plan (QAPP) or a Sampling and Analysis Plan (SAP), which translates project objectives and specifications into directions for those that will implement the project and assess the results.

9.2 Energy calibration check -- To determine whether an FPXRF instrument is operating within resolution and stability tolerances, an energy calibration check should be run. The energy calibration check determines whether the characteristic x-ray lines are shifting,

which would indicate drift within the instrument. As discussed in Sec. 4.10, this check also serves as a gain check in the event that ambient temperatures are fluctuating greatly (more than 10 °F).

9.2.1 The energy calibration check should be run at a frequency consistent with manufacturer's recommendations. Generally, this would be at the beginning of each working day, after the batteries are changed or the instrument is shut off, at the end of each working day, and at any other time when the instrument operator believes that drift is occurring during analysis. A pure element such as iron, manganese, copper, or lead is often used for the energy calibration check. A manufacturer-recommended count time per source should be used for the check.

9.2.2 The instrument manufacturer's manual specifies the channel or kiloelectron volt level at which a pure element peak should appear and the expected intensity of the peak. The intensity and channel number of the pure element as measured using the source should be checked and compared to the manufacturer's recommendation. If the energy calibration check does not meet the manufacturer's criteria, then the pure element sample should be repositioned and reanalyzed. If the criteria are still not met, then an energy calibration should be performed as described in the manufacturer's manual. With some FPXRF instruments, once a spectrum is acquired from the energy calibration check, the peak can be optimized and realigned to the manufacturer's specifications using their software.

9.3 Blank samples -- Two types of blank samples should be analyzed for FPXRF analysis, specifically, instrument blanks and method blanks.

9.3.1 An instrument blank is used to verify that no contamination exists in the spectrometer or on the probe window. The instrument blank can be silicon dioxide, a polytetrafluoroethylene (PTFE) block, a quartz block, "clean" sand, or lithium carbonate. This instrument blank should be analyzed on each working day before and after analyses are conducted and once per every twenty samples. An instrument blank should also be analyzed whenever contamination is suspected by the analyst. The frequency of analysis will vary with the data quality objectives of the project. A manufacturer-recommended count time per source should be used for the blank analysis. No element concentrations above the established lower limit of detection should be found in the instrument blank. If concentrations exceed these limits, then the probe window and the check sample should be checked for contamination. If contamination is not a problem, then the instrument must be "zeroed" by following the manufacturer's instructions.

9.3.2 A method blank is used to monitor for laboratory-induced contaminants or interferences. The method blank can be "clean" silica sand or lithium carbonate that undergoes the same preparation procedure as the samples. A method blank must be analyzed at least daily. The frequency of analysis will depend on the data quality objectives of the project. If the method blank does not contain the target analyte at a level that interferes with the project-specific data quality objectives then the method blank would be considered acceptable. In the absence of project-specific data quality objectives, if the blank is less than the lowest level of detection or less than 10% of the lowest sample concentration for the analyte, whichever is greater, then the method blank would be considered acceptable. If the method blank cannot be considered acceptable, the cause of the problem must be identified, and all samples analyzed with the method blank must be reanalyzed.

9.4 Calibration verification checks -- A calibration verification check sample is used to check the accuracy of the instrument and to assess the stability and consistency of the analysis for the analytes of interest. A check sample should be analyzed at the beginning of each working day, during active sample analyses, and at the end of each working day. The frequency of calibration checks during active analysis will depend on the data quality objectives of the project. The check sample should be a well characterized soil sample from the site that is representative of site samples in terms of particle size and degree of homogeneity and that contains contaminants at concentrations near the action levels. If a site-specific sample is not available, then an NIST or other SRM that contains the analytes of interest can be used to verify the accuracy of the instrument. The measured value for each target analyte should be within  $\pm 20$  percent (%D) of the true value for the calibration verification check to be acceptable. If a measured value falls outside this range, then the check sample should be reanalyzed. If the value continues to fall outside the acceptance range, the instrument should be recalibrated, and the batch of samples analyzed before the unacceptable calibration verification check must be reanalyzed.

9.5 Precision measurements -- The precision of the method is monitored by analyzing a sample with low, moderate, or high concentrations of target analytes. The frequency of precision measurements will depend on the data quality objectives for the data. A minimum of one precision sample should be run per day. Each precision sample should be analyzed 7 times in replicate. It is recommended that precision measurements be obtained for samples with varying concentration ranges to assess the effect of concentration on method precision. Determining method precision for analytes at concentrations near the site action levels can be extremely important if the FPXRF results are to be used in an enforcement action; therefore, selection of at least one sample with target analyte concentrations at or near the site action levels or levels of concern is recommended. A precision sample is analyzed by the instrument for the same field analysis time as used for other project samples. The relative standard deviation (RSD) of the sample mean is used to assess method precision. For FPXRF data to be considered adequately precise, the RSD should not be greater than 20 percent with the exception of chromium. RSD values for chromium should not be greater than 30 percent. If both in situ and intrusive analytical techniques are used during the course of one day, it is recommended that separate precision calculations be performed for each analysis type.

The equation for calculating RSD is as follows:

$$\text{RSD} = (\text{SD} / \text{Mean Concentration}) \times 100$$

where:

RSD	=	Relative standard deviation for the precision measurement for the analyte
SD	=	Standard deviation of the concentration for the analyte
Mean concentration	=	Mean concentration for the analyte

The precision or reproducibility of a measurement will improve with increasing count time, however, increasing the count time by a factor of 4 will provide only 2 times better precision, so there is a point of diminishing return. Increasing the count time also improves the sensitivity, but decreases sample throughput.

9.6 The lower limits of detection should be established from actual measured performance based on spike recoveries in the matrix of concern or from acceptable method performance on a certified reference material of the appropriate matrix and within the appropriate calibration range for the application. This is considered the best estimate of the true method sensitivity as opposed to a statistical determination based on the standard deviation of

replicate analyses of a low-concentration sample. While the statistical approach demonstrates the potential data variability for a given sample matrix at one point in time, it does not represent what can be detected or most importantly the lowest concentration that can be calibrated. For this reason the sensitivity should be established as the lowest point of detection based on acceptable target analyte recovery in the desired sample matrix.

9.7 Confirmatory samples -- The comparability of the FPXRF analysis is determined by submitting FPXRF-analyzed samples for analysis at a laboratory. The method of confirmatory analysis must meet the project and XRF measurement data quality objectives. The confirmatory samples must be splits of the well homogenized sample material. In some cases the prepared sample cups can be submitted. A minimum of 1 sample for each 20 FPXRF-analyzed samples should be submitted for confirmatory analysis. This frequency will depend on project-specific data quality objectives. The confirmatory analyses can also be used to verify the quality of the FPXRF data. The confirmatory samples should be selected from the lower, middle, and upper range of concentrations measured by the FPXRF. They should also include samples with analyte concentrations at or near the site action levels. The results of the confirmatory analysis and FPXRF analyses should be evaluated with a least squares linear regression analysis. If the measured concentrations span more than one order of magnitude, the data should be log-transformed to standardize variance which is proportional to the magnitude of measurement. The correlation coefficient ( $r$ ) for the results should be 0.7 or greater for the FPXRF data to be considered screening level data. If the  $r$  is 0.9 or greater and inferential statistics indicate the FPXRF data and the confirmatory data are statistically equivalent at a 99 percent confidence level, the data could potentially meet definitive level data criteria.

## 10.0 CALIBRATION AND STANDARDIZATION

10.1 Instrument calibration -- Instrument calibration procedures vary among FPXRF instruments. Users of this method should follow the calibration procedures outlined in the operator's manual for each specific FPXRF instrument. Generally, however, three types of calibration procedures exist for FPXRF instruments, namely: FP calibration, empirical calibration, and the Compton peak ratio or normalization method. These three types of calibration are discussed below.

10.2 Fundamental parameters calibration -- FP calibration procedures are extremely variable. An FP calibration provides the analyst with a "standardless" calibration. The advantages of FP calibrations over empirical calibrations include the following:

- No previously collected site-specific samples are necessary, although site-specific samples with confirmed and validated analytical results for all elements present could be used.
- Cost is reduced because fewer confirmatory laboratory results or calibration standards are necessary.

However, the analyst should be aware of the limitations imposed on FP calibration by particle size and matrix effects. These limitations can be minimized by adhering to the preparation procedure described in Sec. 7.3. The two FP calibration processes discussed below are based on an effective energy FP routine and a back scatter with FP (BFP) routine. Each FPXRF FP calibration process is based on a different iterative algorithmic method. The calibration procedure for each routine is explained in detail in the manufacturer's user manual for each FPXRF instrument; in addition, training courses are offered for each instrument.

10.2.1 Effective energy FP calibration -- The effective energy FP calibration is performed by the manufacturer before an instrument is sent to the analyst. Although SSCS can be used, the calibration relies on pure element standards or SRMs such as those obtained from NIST for the FP calibration. The effective energy routine relies on the spectrometer response to pure elements and FP iterative algorithms to compensate for various matrix effects.

Alpha coefficients are calculated using a variation of the Sherman equation, which calculates theoretical intensities from the measurement of pure element samples. These coefficients indicate the quantitative effect of each matrix element on an analyte's measured x-ray intensity. Next, the Lachance Traill algorithm is solved as a set of simultaneous equations based on the theoretical intensities. The alpha coefficients are then downloaded into the specific instrument.

The working effective energy FP calibration curve must be verified before sample analysis begins on each working day, after every 20 samples are analyzed, and at the end of sampling. This verification is performed by analyzing either an NIST SRM or an SSCS that is representative of the site-specific samples. This SRM or SSCS serves as a calibration check. A manufacturer-recommended count time per source should be used for the calibration check. The analyst must then adjust the y-intercept and slope of the calibration curve to best fit the known concentrations of target analytes in the SRM or SSCS.

A percent difference (%D) is then calculated for each target analyte. The %D should be within  $\pm 20$  percent of the certified value for each analyte. If the %D falls outside this acceptance range, then the calibration curve should be adjusted by varying the slope of the line or the y-intercept value for the analyte. The SRM or SSCS is reanalyzed until the %D falls within  $\pm 20$  percent. The group of 20 samples analyzed before an out-of-control calibration check should be reanalyzed.

The equation to calibrate %D is as follows:

$$\%D = ((C_s - C_k) / C_k) \times 100$$

where:

%D = Percent difference

$C_k$  = Certified concentration of standard sample

$C_s$  = Measured concentration of standard sample

10.2.2 BFP calibration -- BFP calibration relies on the ability of the liquid nitrogen-cooled, Si(Li) solid-state detector to separate the coherent (Compton) and incoherent (Rayleigh) backscatter peaks of primary radiation. These peak intensities are known to be a function of sample composition, and the ratio of the Compton to Rayleigh peak is a function of the mass absorption of the sample. The calibration procedure is explained in detail in the instrument manufacturer's manual. Following is a general description of the BFP calibration procedure.

The concentrations of all detected and quantified elements are entered into the computer software system. Certified element results for an NIST SRM or confirmed and validated results for an SSCS can be used. In addition, the concentrations of oxygen and silicon must be entered; these two concentrations are not found in standard metals analyses. The manufacturer provides silicon and oxygen concentrations for typical soil types. Pure element standards are then analyzed using a manufacturer-recommended

count time per source. The results are used to calculate correction factors in order to adjust for spectrum overlap of elements.

The working BFP calibration curve must be verified before sample analysis begins on each working day, after every 20 samples are analyzed, and at the end of the analysis. This verification is performed by analyzing either an NIST SRM or an SSCS that is representative of the site-specific samples. This SRM or SSCS serves as a calibration check. The standard sample is analyzed using a manufacturer-recommended count time per source to check the calibration curve. The analyst must then adjust the y-intercept and slope of the calibration curve to best fit the known concentrations of target analytes in the SRM or SSCS.

A %D is then calculated for each target analyte. The %D should fall within  $\pm 20$  percent of the certified value for each analyte. If the %D falls outside this acceptance range, then the calibration curve should be adjusted by varying the slope of the line the y-intercept value for the analyte. The standard sample is reanalyzed until the %D falls within  $\pm 20$  percent. The group of 20 samples analyzed before an out-of-control calibration check should be reanalyzed.

10.3 Empirical calibration -- An empirical calibration can be performed with SSCS, site-typical standards, or standards prepared from metal oxides. A discussion of SSCS is included in Sec. 7.3; if no previously characterized samples exist for a specific site, site-typical standards can be used. Site-typical standards may be selected from commercially available characterized soils or from SSCS prepared for another site. The site-typical standards should closely approximate the site's soil matrix with respect to particle size distribution, mineralogy, and contaminant analytes. If neither SSCS nor site-typical standards are available, it is possible to make gravimetric standards by adding metal oxides to a "clean" sand or silicon dioxide matrix that simulates soil. Metal oxides can be purchased from various chemical vendors. If standards are made on site, a balance capable of weighing items to at least two decimal places is necessary. Concentrated ICP or AA standard solutions can also be used to make standards. These solutions are available in concentrations of 10,000 parts per million, thus only small volumes have to be added to the soil.

An empirical calibration using SSCS involves analysis of SSCS by the FPXRF instrument and by a conventional analytical method such as ICP or AA. A total acid digestion procedure should be used by the laboratory for sample preparation. Generally, a minimum of 10 and a maximum of 30 well characterized SSCS, site-typical standards, or prepared metal oxide standards are necessary to perform an adequate empirical calibration. The exact number of standards depends on the number of analytes of interest and interfering elements. Theoretically, an empirical calibration with SSCS should provide the most accurate data for a site because the calibration compensates for site-specific matrix effects.

The first step in an empirical calibration is to analyze the pure element standards for the elements of interest. This enables the instrument to set channel limits for each element for spectral deconvolution. Next the SSCS, site-typical standards, or prepared metal oxide standards are analyzed using a count time of 200 seconds per source or a count time recommended by the manufacturer. This will produce a spectrum and net intensity of each analyte in each standard. The analyte concentrations for each standard are then entered into the instrument software; these concentrations are those obtained from the laboratory, the certified results, or the gravimetrically determined concentrations of the prepared standards. This gives the instrument analyte values to regress against corresponding intensities during the modeling stage. The regression equation correlates the concentrations of an analyte with its net intensity.

The calibration equation is developed using a least squares fit regression analysis. After the regression terms to be used in the equation are defined, a mathematical equation can be developed to calculate the analyte concentration in an unknown sample. In some FPXRF instruments, the software of the instrument calculates the regression equation. The software uses calculated intercept and slope values to form a multiterm equation. In conjunction with the software in the instrument, the operator can adjust the multiterm equation to minimize interelement interferences and optimize the intensity calibration curve.

It is possible to define up to six linear or nonlinear terms in the regression equation. Terms can be added and deleted to optimize the equation. The goal is to produce an equation with the smallest regression error and the highest correlation coefficient. These values are automatically computed by the software as the regression terms are added, deleted, or modified. It is also possible to delete data points from the regression line if these points are significant outliers or if they are heavily weighing the data. Once the regression equation has been selected for an analyte, the equation can be entered into the software for quantitation of analytes in subsequent samples. For an empirical calibration to be acceptable, the regression equation for a specific analyte should have a correlation coefficient of 0.98 or greater or meet the DQOs of the project.

In an empirical calibration, one must apply the DQOs of the project and ascertain critical or action levels for the analytes of interest. It is within these concentration ranges or around these action levels that the FPXRF instrument should be calibrated most accurately. It may not be possible to develop a good regression equation over several orders of analyte concentration.

10.4 Compton normalization method -- The Compton normalization method is based on analysis of a single, certified standard and normalization for the Compton peak. The Compton peak is produced from incoherent backscattering of x-ray radiation from the excitation source and is present in the spectrum of every sample. The Compton peak intensity changes with differing matrices. Generally, matrices dominated by lighter elements produce a larger Compton peak, and those dominated by heavier elements produce a smaller Compton peak. Normalizing to the Compton peak can reduce problems with varying matrix effects among samples. Compton normalization is similar to the use of internal standards in organics analysis. The Compton normalization method may not be effective when analyte concentrations exceed a few percent.

The certified standard used for this type of calibration could be an NIST SRM such as 2710 or 2711. The SRM must be a matrix similar to the samples and must contain the analytes of interests at concentrations near those expected in the samples. First, a response factor has to be determined for each analyte. This factor is calculated by dividing the net peak intensity by the analyte concentration. The net peak intensity is gross intensity corrected for baseline reading. Concentrations of analytes in samples are then determined by multiplying the baseline corrected analyte signal intensity by the normalization factor and by the response factor. The normalization factor is the quotient of the baseline corrected Compton  $K_{\alpha}$  peak intensity of the SRM divided by that of the samples. Depending on the FPXRF instrument used, these calculations may be done manually or by the instrument software.

## 11.0 PROCEDURE

11.1 Operation of the various FPXRF instruments will vary according to the manufacturers' protocols. Before operating any FPXRF instrument, one should consult the manufacturer's manual. Most manufacturers recommend that their instruments be allowed to warm up for 15 to 30 minutes before analysis of samples. This will help alleviate drift or energy calibration problems later during analysis.

11.2 Each FPXRF instrument should be operated according to the manufacturer's recommendations. There are two modes in which FPXRF instruments can be operated: in situ and intrusive. The in situ mode involves analysis of an undisturbed soil sediment or sample. Intrusive analysis involves collection and preparation of a soil or sediment sample before analysis. Some FPXRF instruments can operate in both modes of analysis, while others are designed to operate in only one mode. The two modes of analysis are discussed below.

11.3 For in situ analysis, remove any large or nonrepresentative debris from the soil surface before analysis. This debris includes rocks, pebbles, leaves, vegetation, roots, and concrete. Also, the soil surface must be as smooth as possible so that the probe window will have good contact with the surface. This may require some leveling of the surface with a stainless-steel trowel. During the study conducted to provide example performance data for this method, this modest amount of sample preparation was found to take less than 5 min per sample location. The last requirement is that the soil or sediment not be saturated with water. Manufacturers state that their FPXRF instruments will perform adequately for soils with moisture contents of 5 to 20 percent but will not perform well for saturated soils, especially if ponded water exists on the surface. Another recommended technique for in situ analysis is to tamp the soil to increase soil density and compactness for better repeatability and representativeness. This condition is especially important for heavy element analysis, such as barium. Source count times for in situ analysis usually range from 30 to 120 seconds, but source count times will vary among instruments and depending on the desired method sensitivity. Due to the heterogeneous nature of the soil sample, in situ analysis can provide only "screening" type data.

11.4 For intrusive analysis of surface or sediment, it is recommended that a sample be collected from a 4- by 4-inch square that is 1 inch deep. This will produce a soil sample of approximately 375 g or 250 cm<sup>3</sup>, which is enough soil to fill an 8-ounce jar. However, the exact dimensions and sample depth should take into consideration the heterogeneous deposition of contaminants and will ultimately depend on the desired project-specific data quality objectives. The sample should be homogenized, dried, and ground before analysis. The sample can be homogenized before or after drying. The homogenization technique to be used after drying is discussed in Sec. 4.2. If the sample is homogenized before drying, it should be thoroughly mixed in a beaker or similar container, or if the sample is moist and has a high clay content, it can be kneaded in a plastic bag. One way to monitor homogenization when the sample is kneaded in a plastic bag is to add sodium fluorescein dye to the sample. After the moist sample has been homogenized, it is examined under an ultraviolet light to assess the distribution of sodium fluorescein throughout the sample. If the fluorescent dye is evenly distributed in the sample, homogenization is considered complete; if the dye is not evenly distributed, mixing should continue until the sample has been thoroughly homogenized. During the study conducted to provide data for this method, the time necessary for homogenization procedure using the fluorescein dye ranged from 3 to 5 min per sample. As demonstrated in Secs. 13.5 and 13.7, homogenization has the greatest impact on the reduction of sampling variability. It produces little or no contamination. Often, the direct analysis through the plastic bag is possible without the more labor intensive steps of drying, grinding, and sieving given in Secs. 11.5 and 11.6. Of course, to achieve the best data quality possible all four steps should be followed.

11.5 Once the soil or sediment sample has been homogenized, it should be dried. This can be accomplished with a toaster oven or convection oven. A small aliquot of the sample (20 to 50 g) is placed in a suitable container for drying. The sample should be dried for 2 to 4 hr in the convection or toaster oven at a temperature not greater than 150 °C. Samples may also be air dried under ambient temperature conditions using a 10- to 20-g portion. Regardless of what drying mechanism is used, the drying process is considered complete when a constant sample weight can be obtained. Care should be taken to avoid sample cross-contamination and these measures can be evaluated by including an appropriate method blank sample along with any sample preparation process.



**CAUTION:** Microwave drying is not a recommended procedure. Field studies have shown that microwave drying can increase variability between the FPXRF data and confirmatory analysis. High levels of metals in a sample can cause arcing in the microwave oven, and sometimes slag forms in the sample. Microwave oven drying can also melt plastic containers used to hold the sample.

11.6 The homogenized dried sample material should be ground with a mortar and pestle and passed through a 60-mesh sieve to achieve a uniform particle size. Sample grinding should continue until at least 90 percent of the original sample passes through the sieve. The grinding step normally takes an average of 10 min per sample. An aliquot of the sieved sample should then be placed in a 31.0-mm polyethylene sample cup (or equivalent) for analysis. The sample cup should be one-half to three-quarters full at a minimum. The sample cup should be covered with a 2.5  $\mu$ m Mylar (or equivalent) film for analysis. The rest of the soil sample should be placed in a jar, labeled, and archived for possible confirmation analysis. All equipment including the mortar, pestle, and sieves must be thoroughly cleaned so that any cross-contamination is below the established lower limit of detection of the procedure or DQOs of the analysis. If all recommended sample preparation steps are followed, there is a high probability the desired laboratory data quality may be obtained.

## 12.0 DATA ANALYSIS AND CALCULATIONS

Most FPXRF instruments have software capable of storing all analytical results and spectra. The results are displayed in ppm and can be downloaded to a personal computer, which can be used to provide a hard copy printout. Individual measurements that are smaller than three times their associated SD should not be used for quantitation. See the manufacturer's instructions regarding data analysis and calculations.

## 13.0 METHOD PERFORMANCE

13.1 Performance data and related information are provided in SW-846 methods only as examples and guidance. The data do not represent required performance criteria for users of the methods. Instead, performance criteria should be developed on a project-specific basis, and the laboratory should establish in-house QC performance criteria for the application of this method. These performance data are not intended to be and must not be used as absolute QC acceptance criteria for purposes of laboratory accreditation.

13.2 The sections to follow discuss three performance evaluation factors; namely, precision, accuracy, and comparability. The example data presented in Tables 4 through 8 were generated from results obtained from six FPXRF instruments (see Sec. 13.3). The soil samples analyzed by the six FPXRF instruments were collected from two sites in the United States. The soil samples contained several of the target analytes at concentrations ranging from "nondetect" to tens of thousands of mg/kg. These data are provided for guidance purposes only.

13.3 The six FPXRF instruments included the TN 9000 and TN Lead Analyzer manufactured by TN Spectrace; the X-MET 920 with a SiLi detector and X-MET 920 with a gas-filled proportional detector manufactured by Metorex, Inc.; the XL Spectrum Analyzer manufactured by Niton; and the MAP Spectrum Analyzer manufactured by Scitec. The TN 9000 and TN Lead Analyzer both have a HgI<sub>2</sub> detector. The TN 9000 utilized an Fe-55, Cd-109, and Am-241 source. The TN Lead Analyzer had only a Cd-109 source. The X-Met 920 with the SiLi detector had a Cd-109 and Am-241 source. The X-MET 920 with the gas-filled proportional detector had only a Cd-109 source. The XL Spectrum Analyzer utilized a silicon pin-diode

detector and a Cd-109 source. The MAP Spectrum Analyzer utilized a solid-state silicon detector and a Cd-109 source.

13.4 All example data presented in Tables 4 through 8 were generated using the following calibrations and source count times. The TN 9000 and TN Lead Analyzer were calibrated using fundamental parameters using NIST SRM 2710 as a calibration check sample. The TN 9000 was operated using 100, 60, and 60 second count times for the Cd-109, Fe-55, and Am-241 sources, respectively. The TN Lead analyzer was operated using a 60 second count time for the Cd-109 source. The X-MET 920 with the Si(Li) detector was calibrated using fundamental parameters and one well characterized site-specific soil standard as a calibration check. It used 140 and 100 second count times for the Cd-109 and Am-241 sources, respectively. The X-MET 920 with the gas-filled proportional detector was calibrated empirically using between 10 and 20 well characterized site-specific soil standards. It used 120 second times for the Cd-109 source. The XL Spectrum Analyzer utilized NIST SRM 2710 for calibration and the Compton peak normalization procedure for quantitation based on 60 second count times for the Cd-109 source. The MAP Spectrum Analyzer was internally calibrated by the manufacturer. The calibration was checked using a well-characterized site-specific soil standard. It used 240 second times for the Cd-109 source.

13.5 Precision measurements -- The example precision data are presented in Table 4. These data are provided for guidance purposes only. Each of the six FPXRF instruments performed 10 replicate measurements on 12 soil samples that had analyte concentrations ranging from "nondetects" to thousands of mg/kg. Each of the 12 soil samples underwent 4 different preparation techniques from in situ (no preparation) to dried and ground in a sample cup. Therefore, there were 48 precision data points for five of the instruments and 24 precision points for the MAP Spectrum Analyzer. The replicate measurements were taken using the source count times discussed at the beginning of this section.

For each detectable analyte in each precision sample a mean concentration, standard deviation, and RSD was calculated for each analyte. The data presented in Table 4 is an average RSD for the precision samples that had analyte concentrations at 5 to 10 times the lower limit of detection for that analyte for each instrument. Some analytes such as mercury, selenium, silver, and thorium were not detected in any of the precision samples so these analytes are not listed in Table 4. Some analytes such as cadmium, nickel, and tin were only detected at concentrations near the lower limit of detection so that an RSD value calculated at 5 to 10 times this limit was not possible.

One FPXRF instrument collected replicate measurements on an additional nine soil samples to provide a better assessment of the effect of sample preparation on precision. Table 5 shows these results. These data are provided for guidance purposes only. The additional nine soil samples were comprised of three from each texture and had analyte concentrations ranging from near the lower limit of detection for the FPXRF analyzer to thousands of mg/kg. The FPXRF analyzer only collected replicate measurements from three of the preparation methods; no measurements were collected from the in situ homogenized samples. The FPXRF analyzer conducted five replicate measurements of the in situ field samples by taking measurements at five different points within the 4-inch by 4-inch sample square. Ten replicate measurements were collected for both the intrusive undried and unground and intrusive dried and ground samples contained in cups. The cups were shaken between each replicate measurement.

Table 5 shows that the precision dramatically improved from the in situ to the intrusive measurements. In general there was a slight improvement in precision when the sample was dried and ground. Two factors caused the precision for the in situ measurements to be poorer. The major factor is soil heterogeneity. By moving the probe within the 4-inch by 4-inch square,

measurements of different soil samples were actually taking place within the square. Table 5 illustrates the dominant effect of soil heterogeneity. It overwhelmed instrument precision when the FPXRF analyzer was used in this mode. The second factor that caused the RSD values to be higher for the in situ measurements is the fact that only five instead of ten replicates were taken. A lesser number of measurements caused the standard deviation to be larger which in turn elevated the RSD values.

13.6 Accuracy measurements -- Five of the FPXRF instruments (not including the MAP Spectrum Analyzer) analyzed 18 SRMs using the source count times and calibration methods given at the beginning of this section. The 18 SRMs included 9 soil SRMs, 4 stream or river sediment SRMs, 2 sludge SRMs, and 3 ash SRMs. Each of the SRMs contained known concentrations of certain target analytes. A percent recovery was calculated for each analyte in each SRM for each FPXRF instrument. Table 6 presents a summary of this data. With the exception of cadmium, chromium, and nickel, the values presented in Table 6 were generated from the 13 soil and sediment SRMs only. The 2 sludge and 3 ash SRMs were included for cadmium, chromium, and nickel because of the low or nondetectable concentrations of these three analytes in the soil and sediment SRMs.

Only 12 analytes are presented in Table 6. These are the analytes that are of environmental concern and provided a significant number of detections in the SRMs for an accuracy assessment. No data is presented for the X-MET 920 with the gas-filled proportional detector. This FPXRF instrument was calibrated empirically using site-specific soil samples. The percent recovery values from this instrument were very sporadic and the data did not lend itself to presentation in Table 6.

Table 7 provides a more detailed summary of accuracy data for one particular FPXRF instrument (TN 9000) for the 9 soil SRMs and 4 sediment SRMs. These data are provided for guidance purposes only. Table 7 shows the certified value, measured value, and percent recovery for five analytes. These analytes were chosen because they are of environmental concern and were most prevalently certified for in the SRM and detected by the FPXRF instrument. The first nine SRMs are soil and the last 4 SRMs are sediment. Percent recoveries for the four NIST SRMs were often between 90 and 110 percent for all analytes.

13.7 Comparability -- Comparability refers to the confidence with which one data set can be compared to another. In this case, FPXRF data generated from a large study of six FPXRF instruments was compared to SW-846 Methods 3050 and 6010 which are the standard soil extraction for metals and analysis by inductively coupled plasma. An evaluation of comparability was conducted by using linear regression analysis. Three factors were determined using the linear regression. These factors were the y-intercept, the slope of the line, and the coefficient of determination ( $r^2$ ).

As part of the comparability assessment, the effects of soil type and preparation methods were studied. Three soil types (textures) and four preparation methods were examined during the study. The preparation methods evaluated the cumulative effect of particle size, moisture, and homogenization on comparability. Due to the large volume of data produced during this study, linear regression data for six analytes from only one FPXRF instrument is presented in Table 8. Similar trends in the data were seen for all instruments. These data are provided for guidance purposes only.

Table 8 shows the regression parameters for the whole data set, broken out by soil type, and by preparation method. These data are provided for guidance purposes only. The soil types are as follows: soil 1--sand; soil 2--loam; and soil 3--silty clay. The preparation methods are as follows: preparation 1--in situ in the field; preparation 2--intrusive, sample collected and homogenized; preparation 3--intrusive, with sample in a sample cup but sample still wet and not

ground; and preparation 4—intrusive, with sample dried, ground, passed through a 40-mesh sieve, and placed in sample cup.

For arsenic, copper, lead, and zinc, the comparability to the confirmatory laboratory was excellent with  $r^2$  values ranging from 0.80 to 0.99 for all six FPXRF instruments. The slopes of the regression lines for arsenic, copper, lead, and zinc, were generally between 0.90 and 1.00 indicating the data would need to be corrected very little or not at all to match the confirmatory laboratory data. The  $r^2$  values and slopes of the regression lines for barium and chromium were not as good as for the other for analytes, indicating the data would have to be corrected to match the confirmatory laboratory.

Table 8 demonstrates that there was little effect of soil type on the regression parameters for any of the six analytes. The only exceptions were for barium in soil 1 and copper in soil 3. In both of these cases, however, it is actually a concentration effect and not a soil effect causing the poorer comparability. All barium and copper concentrations in soil 1 and 3, respectively, were less than 350 mg/kg.

Table 8 shows there was a preparation effect on the regression parameters for all six analytes. With the exception of chromium, the regression parameters were primarily improved going from preparation 1 to preparation 2. In this step, the sample was removed from the soil surface, all large debris was removed, and the sample was thoroughly homogenized. The additional two preparation methods did little to improve the regression parameters. This data indicates that homogenization is the most critical factor when comparing the results. It is essential that the sample sent to the confirmatory laboratory match the FPXRF sample as closely as possible.

Sec. 11.0 of this method discusses the time necessary for each of the sample preparation techniques. Based on the data quality objectives for the project, an analyst must decide if it is worth the extra time necessary to dry and grind the sample for small improvements in comparability. Homogenization requires 3 to 5 min. Drying the sample requires one to two hours. Grinding and sieving requires another 10 to 15 min per sample. Lastly, when grinding and sieving is conducted, time has to be allotted to decontaminate the mortars, pestles, and sieves. Drying and grinding the samples and decontamination procedures will often dictate that an extra person be on site so that the analyst can keep up with the sample collection crew. The cost of requiring an extra person on site to prepare samples must be balanced with the gain in data quality and sample throughput.

13.8 The following documents may provide additional guidance and insight on this method and technique:

13.8.1 A. D. Hewitt, "Screening for Metals by X-ray Fluorescence Spectrometry/Response Factor/Compton  $K_\alpha$  Peak Normalization Analysis," American Environmental Laboratory, pp 24-32, 1994.

13.8.2 S. Piorek and J. R. Pasmore, "Standardless, In Situ Analysis of Metallic Contaminants in the Natural Environment With a PC-Based, High Resolution Portable X-Ray Analyzer," Third International Symposium on Field Screening Methods for Hazardous Waste and Toxic Chemicals, Las Vegas, Nevada, February 24-26, 1993, Vol 2, pp 1135-1151, 1993.

13.8.3 S. Shefsky, "Sample Handling Strategies for Accurate Lead-in-soil Measurements in the Field and Laboratory," *International Symposium of Field Screening Methods for Hazardous Waste and Toxic Chemicals*, Las Vegas, NV, January 29-31, 1997.

## 14.0 POLLUTION PREVENTION

14.1 Pollution prevention encompasses any technique that reduces or eliminates the quantity and/or toxicity of waste at the point of generation. Numerous opportunities for pollution prevention exist in laboratory operation. The EPA has established a preferred hierarchy of environmental management techniques that places pollution prevention as the management option of first choice. Whenever feasible, laboratory personnel should use pollution prevention techniques to address their waste generation. When wastes cannot be feasibly reduced at the source, the Agency recommends recycling as the next best option.

14.2 For information about pollution prevention that may be applicable to laboratories and research institutions consult *Less is Better: Laboratory Chemical Management for Waste Reduction* available from the American Chemical Society's Department of Government Relations and Science Policy, 1155 16th St., N.W. Washington, D.C. 20036, <http://www.acs.org>.

## 15.0 WASTE MANAGEMENT

The Environmental Protection Agency requires that laboratory waste management practices be conducted consistent with all applicable rules and regulations. The Agency urges laboratories to protect the air, water, and land by minimizing and controlling all releases from hoods and bench operations, complying with the letter and spirit of any sewer discharge permits and regulations, and by complying with all solid and hazardous waste regulations, particularly the hazardous waste identification rules and land disposal restrictions. For further information on waste management, consult *The Waste Management Manual for Laboratory Personnel* available from the American Chemical Society at the address listed in Sec. 14.2.

## 16.0 REFERENCES

1. Metorex, X-MET 920 User's Manual.
2. Spectrace Instruments, "Energy Dispersive X-ray Fluorescence Spectrometry: An Introduction," 1994.
3. TN Spectrace, Spectrace 9000 Field Portable/Benchtop XRF Training and Applications Manual.
4. Unpublished SITE data, received from PRC Environment Management, Inc.

## 17.0 TABLES, DIAGRAMS, FLOWCHARTS, AND VALIDATION DATA

The following pages contain the tables referenced by this method. A flow diagram of the procedure follows the tables.

TABLE 1

## EXAMPLE INTERFERENCE FREE LOWER LIMITS OF DETECTION

Analyte	Chemical Abstract Series Number	Lower Limit of Detection in Quartz Sand (milligrams per kilogram)
Antimony (Sb)	7440-36-0	40
Arsenic (As)	7440-38-0	40
Barium (Ba)	7440-39-3	20
Cadmium (Cd)	7440-43-9	100
Calcium (Ca)	7440-70-2	70
Chromium (Cr)	7440-47-3	150
Cobalt (Co)	7440-48-4	60
Copper (Cu)	7440-50-8	50
Iron (Fe)	7439-89-6	60
Lead (Pb)	7439-92-1	20
Manganese (Mn)	7439-96-5	70
Mercury (Hg)	7439-97-6	30
Molybdenum (Mo)	7439-93-7	10
Nickel (Ni)	7440-02-0	50
Potassium (K)	7440-09-7	200
Rubidium (Rb)	7440-17-7	10
Selenium (Se)	7782-49-2	40
Silver (Ag)	7440-22-4	70
Strontium (Sr)	7440-24-6	10
Thallium (Tl)	7440-28-0	20
Thorium (Th)	7440-29-1	10
Tin (Sn)	7440-31-5	60
Titanium (Ti)	7440-32-6	50
Vanadium (V)	7440-62-2	50
Zinc (Zn)	7440-66-6	50
Zirconium (Zr)	7440-67-7	10

Source: Refs. 1, 2, and 3

These data are provided for guidance purposes only.

TABLE 2

## SUMMARY OF RADIOISOTOPE SOURCE CHARACTERISTICS

Source	Activity (mCi)	Half-Life (Years)	Excitation Energy (keV)	Elemental Analysis Range	
Fe-55	20-50	2.7	5.9	Sulfur to Chromium Molybdenum to Barium	K Lines L Lines
Cd-109	5-30	1.3	22.1 and 87.9	Calcium to Rhodium Tantalum to Lead Barium to Uranium	K Lines K Lines L Lines
Am-241	5-30	432	26.4 and 59.6	Copper to Thulium Tungsten to Uranium	K Lines L Lines
Cm-244	60-100	17.8	14.2	Titanium to Selenium Lanthanum to Lead	K Lines L Lines

Source: Refs. 1, 2, and 3

TABLE 3

## SUMMARY OF X-RAY TUBE SOURCE CHARACTERISTICS

Anode Material	Recommended Voltage Range (kV)	K-alpha Emission (keV)	Elemental Analysis Range	
Cu	18-22	8.04	Potassium to Cobalt Silver to Gadolinium	K Lines L Lines
Mo	40-50	17.4	Cobalt to Yttrium Europium to Radon	K Lines L Lines
Ag	50-65	22.1	Zinc to Technicium Ytterbium to Neptunium	K Lines L Lines

Source: Ref. 4

Notes: The sample elements excited are chosen by taking as the lower limit the same ratio of excitation line energy to element absorption edge as in Table 2 (approximately 0.45) and the requirement that the excitation line energy be above the element absorption edge as the upper limit (L2 edges used for L lines). K-beta excitation lines were ignored.

TABLE 4

## EXAMPLE PRECISION VALUES

Analyte	Average Relative Standard Deviation for Each Instrument at 5 to 10 Times the Lower Limit of Detection					
	TN 9000	TN Lead Analyzer	X-MET 920 (SiLi Detector)	X-MET 920 (Gas-Filled Detector)	XL Spectrum Analyzer	MAP Spectrum Analyzer
Antimony	6.54	NR	NR	NR	NR	NR
Arsenic	5.33	4.11	3.23	1.91	12.47	6.68
Barium	4.02	NR	3.31	5.91	NR	NR
Cadmium	29.84 <sup>a</sup>	NR	24.80 <sup>a</sup>	NR	NR	NR
Calcium	2.16	NR	NR	NR	NR	NR
Chromium	22.25	25.78	22.72	3.91	30.25	NR
Cobalt	33.90	NR	NR	NR	NR	NR
Copper	7.03	9.11	8.49	9.12	12.77	14.86
Iron	1.78	1.67	1.55	NR	2.30	NR
Lead	6.45	5.93	5.05	7.56	6.97	12.16
Manganese	27.04	24.75	NR	NR	NR	NR
Molybdenum	6.95	NR	NR	NR	12.60	NR
Nickel	30.85 <sup>a</sup>	NR	24.92 <sup>a</sup>	20.92 <sup>a</sup>	NA	NR
Potassium	3.90	NR	NR	NR	NR	NR
Rubidium	13.06	NR	NR	NR	32.69 <sup>a</sup>	NR
Strontium	4.28	NR	NR	NR	8.86	NR
Tin	24.32 <sup>a</sup>	NR	NR	NR	NR	NR
Titanium	4.87	NR	NR	NR	NR	NR
Zinc	7.27	7.48	4.26	2.28	10.95	0.83
Zirconium	3.58	NR	NR	NR	6.49	NR

These data are provided for guidance purposes only.

Source: Ref. 4

<sup>a</sup> These values are biased high because the concentration of these analytes in the soil samples was near the lower limit of detection for that particular FPXRF instrument.

NR Not reported.

NA Not applicable; analyte was reported but was below the established lower limit detection.



TABLE 5

## EXAMPLES OF PRECISION AS AFFECTED BY SAMPLE PREPARATION

Analyte	Average Relative Standard Deviation for Each Preparation Method		
	In Situ-Field	Intrusive- Undried and Unground	Intrusive- Dried and Ground
Antimony	30.1	15.0	14.4
Arsenic	22.5	5.36	3.76
Barium	17.3	3.38	2.90
Cadmium <sup>a</sup>	41.2	30.8	28.3
Calcium	17.5	1.68	1.24
Chromium	17.6	28.5	21.9
Cobalt	28.4	31.1	28.4
Copper	26.4	10.2	7.90
Iron	10.3	1.67	1.57
Lead	25.1	8.55	6.03
Manganese	40.5	12.3	13.0
Mercury	ND	ND	ND
Molybdenum	21.6	20.1	19.2
Nickel <sup>a</sup>	29.8	20.4	18.2
Potassium	18.6	3.04	2.57
Rubidium	29.8	16.2	18.9
Selenium	ND	20.2	19.5
Silver <sup>a</sup>	31.9	31.0	29.2
Strontium	15.2	3.38	3.98
Thallium	39.0	16.0	19.5
Thorium	NR	NR	NR
Tin	ND	14.1	15.3
Titanium	13.3	4.15	3.74
Vanadium	NR	NR	NR
Zinc	26.6	13.3	11.1
Zirconium	20.2	5.63	5.18

These data are provided for guidance purposes only.

Source: Ref. 4

<sup>a</sup> These values may be biased high because the concentration of these analytes in the soil samples was near the lower limit of detection.

ND Not detected.

NR Not reported.

TABLE 6

## EXAMPLE ACCURACY VALUES

Analyte	Instrument															
	TN 9000				TN Lead Analyzer				X-MET 920 (SiLi Detector)				XL Spectrum Analyzer			
	n	Range of % Rec.	Mean % Rec.	SD	n	Range of % Rec.	Mean % Rec.	SD	n	Range of % Rec.	Mean % Rec.	SD	n	Range of % Rec.	Mean % Rec.	SD
Sb	2	100-149	124.3	NA	--	--	--	--	--	--	--	--	--	--	--	--
As	5	68-115	92.8	17.3	5	44-105	83.4	23.2	4	9.7-91	47.7	39.7	5	38-535	189.8	206
Ba	9	98-198	135.3	36.9	--	--	--	--	9	18-848	168.2	262	--	--	--	--
Cd	2	99-129	114.3	NA	--	--	--	--	6	81-202	110.5	45.7	--	--	--	--
Cr	2	99-178	138.4	NA	--	--	--	--	7	22-273	143.1	93.8	3	98-625	279.2	300
Cu	8	61-140	95.0	28.8	6	38-107	79.1	27.0	11	10-210	111.8	72.1	8	95-480	203.0	147
Fe	6	78-155	103.7	26.1	6	89-159	102.3	28.6	6	48-94	80.4	16.2	6	26-187	108.6	52.9
Pb	11	66-138	98.9	19.2	11	68-131	97.4	18.4	12	23-94	72.7	20.9	13	80-234	107.3	39.9
Mn	4	81-104	93.1	9.70	3	92-152	113.1	33.8	--	--	--	--	--	--	--	--
Ni	3	99-122	109.8	12.0	--	--	--	--	--	--	--	--	3	57-123	87.5	33.5
Sr	8	110-178	132.6	23.8	--	--	--	--	--	--	--	--	7	86-209	125.1	39.5
Zn	11	41-130	94.3	24.0	10	81-133	100.0	19.7	12	46-181	106.6	34.7	11	31-199	94.6	42.5

Source: Ref. 4. These data are provided for guidance purposes only.

n: Number of samples that contained a certified value for the analyte and produced a detectable concentration from the FPXRF instrument.

SD: Standard deviation; NA: Not applicable; only two data points, therefore, a SD was not calculated.

%Rec.: Percent recovery.

-- No data.

TABLE 7

EXAMPLE ACCURACY FOR TN 9000<sup>a</sup>

Standard Reference Material	Arsenic			Barium			Copper			Lead			Zinc		
	Cert. Conc.	Meas. Conc.	%Rec.	Cert. Conc.	Meas. Conc.	%Rec.	Cert. Conc.	Meas. Conc.	%Rec.	Cert. Conc.	Meas. Conc.	%Rec.	Cert. Conc.	Meas. Conc.	%Rec.
RTC CRM-021	24.8	ND	NA	586	1135	193.5	4792	2908	60.7	144742	149947	103.6	546	224	40.9
RTC CRM-020	397	429	92.5	22.3	ND	NA	753	583	77.4	5195	3444	66.3	3022	3916	129.6
BCR CRM 143R	--	--	--	--	--	--	131	105	80.5	180	206	114.8	1055	1043	99.0
BCR CRM 141	--	--	--	--	--	--	32.6	ND	NA	29.4	ND	NA	81.3	ND	NA
USGS GXR-2	25.0	ND	NA	2240	2946	131.5	76.0	106	140.2	690	742	107.6	530	596	112.4
USGS GXR-6	330	294	88.9	1300	2581	198.5	66.0	ND	NA	101	80.9	80.1	118	ND	NA
NIST 2711	105	104	99.3	726	801	110.3	114	ND	NA	1162	1172	100.9	350	333	94.9
NIST 2710	626	722	115.4	707	782	110.6	2950	2834	96.1	5532	5420	98.0	6952	6476	93.2
NIST 2709	17.7	ND	NA	968	950	98.1	34.6	ND	NA	18.9	ND	NA	106	98.5	93.0
NIST 2704	23.4	ND	NA	414	443	107.0	98.6	105	106.2	161	167	103.5	438	427	97.4
CNRC PACS-1	211	143	67.7	--	772	NA	452	302	66.9	404	332	82.3	824	611	74.2
SARM-51	--	--	--	335	466	139.1	268	373	139.2	5200	7199	138.4	2200	2676	121.6
SARM-52	--	--	--	410	527	128.5	219	193	88.1	1200	1107	92.2	264	215	81.4

Source: Ref. 4. These data are provided for guidance purposes only.

<sup>a</sup> All concentrations in milligrams per kilogram.

%Rec.: Percent recovery; ND: Not detected; NA: Not applicable.

-- No data.

TABLE 8

EXAMPLE REGRESSION PARAMETERS FOR COMPARABILITY<sup>1</sup>

	Arsenic				Barium				Copper			
	n	r <sup>2</sup>	Int.	Slope	n	r <sup>2</sup>	Int.	Slope	n	r <sup>2</sup>	Int.	Slope
All Data	824	0.94	1.62	0.94	1255	0.71	60.3	0.54	984	0.93	2.19	0.93
Soil 1	368	0.96	1.41	0.95	393	0.05	42.6	0.11	385	0.94	1.26	0.99
Soil 2	453	0.94	1.51	0.96	462	0.56	30.2	0.66	463	0.92	2.09	0.95
Soil 3	—	—	—	—	400	0.85	44.7	0.59	136	0.46	16.60	0.57
Prep 1	207	0.87	2.69	0.85	312	0.64	53.7	0.55	256	0.87	3.89	0.87
Prep 2	208	0.97	1.38	0.95	315	0.67	64.6	0.52	246	0.96	2.04	0.93
Prep 3	204	0.96	1.20	0.99	315	0.78	64.6	0.53	236	0.97	1.45	0.99
Prep 4	205	0.96	1.45	0.98	313	0.81	58.9	0.55	246	0.96	1.99	0.96

	Lead				Zinc				Chromium			
	n	r <sup>2</sup>	Int.	Slope	n	r <sup>2</sup>	Int.	Slope	n	r <sup>2</sup>	Int.	Slope
All Data	1205	0.92	1.66	0.95	1103	0.89	1.86	0.95	280	0.70	64.6	0.42
Soil 1	357	0.94	1.41	0.96	329	0.93	1.78	0.93	—	—	—	—
Soil 2	451	0.93	1.62	0.97	423	0.85	2.57	0.90	—	—	—	—
Soil 3	397	0.90	2.40	0.90	351	0.90	1.70	0.98	186	0.66	38.9	0.50
Prep 1	305	0.80	2.88	0.86	286	0.79	3.16	0.87	105	0.80	66.1	0.43
Prep 2	298	0.97	1.41	0.96	272	0.95	1.86	0.93	77	0.51	81.3	0.36
Prep 3	302	0.98	1.26	0.99	274	0.93	1.32	1.00	49	0.73	53.7	0.45
Prep 4	300	0.96	1.38	1.00	271	0.94	1.41	1.01	49	0.75	31.6	0.56

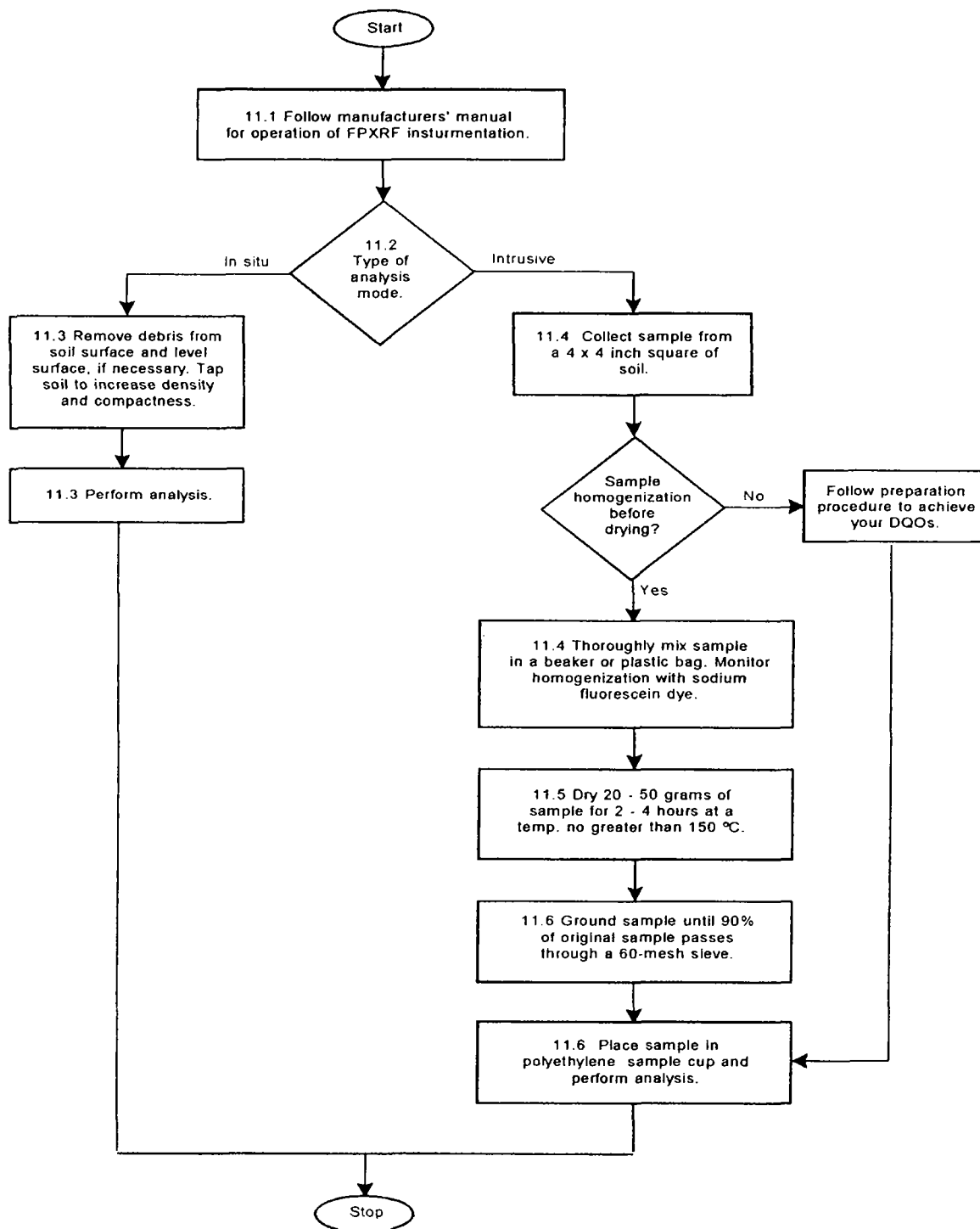
Source: Ref. 4. These data are provided for guidance purposes only.

<sup>1</sup> Log-transformed data

n: Number of data points; r<sup>2</sup>: Coefficient of determination; Int.: Y-intercept

— No applicable data

FIELD PORTABLE X-RAY FLUORESCENCE SPECTROMETRY FOR THE  
DETERMINATION OF ELEMENTAL CONCENTRATIONS IN SOIL AND SEDIMENT



	Standard Operating Procedure	
	<b>Soil Sampling Equipment Decontamination Procedure</b>	

## **1. Applicability**

- 1.1 This Standard Operating Procedure (SOP) covers the decontamination of soil sampling equipment, including split-spoons, hand augers, scoops, or other devices used to collect soil samples. Because of the potential for the decontamination equipment to be a source of contamination, the equipment must be inspected prior to each use for signs of contamination or wear and replaced frequently to prevent cross-contamination of samples.
- 1.2 This SOP does not address health and safety, sample collection, or laboratory analysis.

## **2. Equipment/Supplies**

- 2.1 Detergent (Alconox, Liquinox, TSP, etc.)
- 2.2 Steam distilled water or laboratory grade de-ionized water
- 2.3 Squirt bottle
- 2.4 Scrub brush
- 2.5 5-gallon plastic buckets (2)
- 2.6 Plastic sheeting
- 2.7 Paper towels
- 2.8 Field Log Book

## **3. Procedure**

- 3.1 Prepare a detergent solution in one of the buckets according to the detergent manufacturer's directions.
- 3.2 Partially fill the second bucket with distilled water.
- 3.3 Remove soil or other material on the sampling device with tools or paper towels.

- 3.4 After the materials are removed from the sampling device, immerse the device in the detergent solution and scrub with the brush.
- 3.5 Remove the device from the detergent solution and allow to drain for a moment prior to immersing the device in the rinse water bucket.
- 3.6 Immerse the device in the rinse water bucket and agitate the device.
- 3.7 Remove the device from the rinse water and give the device a final rinse with copious amounts of water from the squirt bottle. Allow the water to drain from the device.
- 3.8 The device may be returned to use. If the device will be stored prior to its next use, cover the device with plastic and store at a location away from potential sources of contamination.

	<p>Standard Operating Procedure</p> <p><b>Low-Flow Groundwater Sampling Procedure</b></p>	
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## 1. Applicability

- 1.1 This Standard Operating Procedure (SOP) covers the collection of groundwater samples from monitoring wells using a low flow technique to minimize the disturbance of particulate matter in the well. This method may be used to collect samples for total metals analysis, organic analysis including volatile organic compounds, and general water chemistry parameters. This method may also be used for the collection of samples for dissolved metals analysis by the addition of a field filtration step.
- 1.2 The presence of the disturbed particulate matter in a groundwater sample will have an affect on the analytical results for total metals. Kearl et al. (1994) recommends using a low flow procedure to obtain representative samples of the total mobile metal load in the groundwater, which includes the dissolved and colloidal portions. The disturbance of the particulate matter in the well is minimized by using a pump to purge and sample the well, inserting (or installing) the pump in the well at least one day prior to sampling (if possible), low flow purging the well prior to sampling, and then sampling the well at a low flow rate (approximately 100mL/min)(Kearl et al., 1994).
- 1.3 This SOP does not address health and safety, water level measurements, decontamination, field filtration, sample preservation, sample bottle filling, chain-of-custody, field parameter analysis, pump operation and maintenance, or laboratory analysis. Refer to other SOPs, the project work plans including the quality assurance project plan, sampling plan, and health and safety plan, as appropriate. Refer to pump manufacturer's operation and maintenance manual for pump operating procedures.

## 2. Pump Selection

- 2.1 The type of pump used to low flow purge and sample the well will have an impact on the chemistry of the groundwater sample. A dedicated, submersible bladder pump is recommended for use with this SOP. A portable, submersible bladder pump may be used if time allows. A peristaltic pump may also be used to collect samples for non-volatile analyses. The potential impact of a peristaltic pump on volatile fractions of samples must be considered on a project specific basis. Other



pumps may be found to be suitable on a project specific basis. The pump and transfer tubing selected for use must be composed of materials that will not affect the sample quality (i.e., stainless steel, tygon, teflon, or other equivalent material) and that will utilize a pumping action that also will not significantly impact sample quality (i.e., positive displacement without aeration). See Parker (1994) for a recent summary of the potential impacts of sampling devices on sample quality.

### **3. Definitions**

- 3.1 Dedicated Pump-A permanently installed pump.
- 3.2 Dissolved Metals-The water sample is filtered in the field prior to the preservation step, and then analyzed in the laboratory.
- 3.3 Low Flow Purging-The purging of “volumes” of water through the sample pump, and transfer tubing only at a low rate with no appreciable drawdown in the well. Puls and Barcelona (1996) recommend that water quality parameters such as pH, temperature and specific conductance stabilize prior to the collection of the water sample. A “volume” is the amount of water contained in the sample pump and the transfer tubing when completely full. Low flow purging is performed with the pump intake located at the midpoint of the well screen.

In a typical well, stagnant water, when present, is located in the solid portion of the well pipe above the screen. Under conditions where low flow sampling is applicable, fresh groundwater is continuously moving through the screened interval of the well according to the existing gradients in the hydrostratigraphic unit. Purging of stagnant groundwater from the entire well is not performed because when the well is pumped at a low rate, the stagnant water from the solid portion of the well pipe above the screened interval does not mix with the fresh groundwater present in the screened interval, resulting in a sample representative of the groundwater in the vicinity of the well.

- 3.4 Total Metals-The water sample is not filtered in the field prior to the preservation step, and then analyzed in the laboratory.
- 3.5 Total Mobile Metals Load-This is similar to 3.4, except that special techniques (i.e., low flow sampling) have been employed to minimize the potential for the presence of particulates in the water sample due to disturbance of the well by the sampling technique (i.e., creating sediment suspended by agitating the well). The water sample is expected to contain the dissolved and colloidal metals being transported in the groundwater (i.e., the mobile constituents).

#### **4. Equipment**

- 4.1 Electronic water level indicator (SOP T103) or water level measuring tape with popper.
- 4.2 Sampling pump and transfer tubing (with centralizer). Use SOP T124 for peristaltic pump.
- 4.3 Well construction logs for each well.
- 4.4 Previous round of water levels and measurements of total well depth (if any).
- 4.5 Watch with ability to accurately measure one minute.
- 4.6 Graduated cylinder or other device to accurately measure 100 mL
- 4.7 Well lock keys
- 4.8 Field Log Book (SOP T102)
- 4.9 Table of pump and transfer tubing volumes
- 4.10 Field Chain-of -Custody SOP T107
- 4.11 Field Filtration SOP T114 (as needed)
- 4.12 Plastic bucket
- 4.13 Plastic sheeting
- 4.14 pH paper
- 4.15 Ice
- 4.16 Coolers
- 4.17 Sample bottles (pre-preserved) (minimum one extra set)
- 4.18 Water sampling log forms
- 4.19 Flow-through cell and pH, conductivity, and turbidity meter (if required)

#### **5. Procedure**

- 5.1 Unlock well and remove cap. Let the well stand open to allow the water level to equilibrate, if necessary. Measure the water level in the well and the total depth of the well (skip total depth measurement for dedicated pump situation, or if total depth is known and the time available to let the well stand undisturbed is limited). Record measurements in field book. Skip to 5.6 if a dedicated pump is in use.  
*Note: It may be appropriate to obtain a complete round of water levels from each of the monitoring wells at the site prior to sampling any of the wells.*
- 5.2 Review the well construction log and determine the depth of the well screen midpoint below the top of casing and the total depth of the well. Record in field book.
- 5.3. Compare the measurement of total depth of the well with the well construction log and previous measurements, if any, to determine available length of well screen. Confer with project manager or field supervisor if a significant accumulation of sediment is present in the well, or other discrepancies are identified. Record in field book.

- 5.4 Insert the pre-cleaned tubing, or pump and tubing into the well to the midpoint of the well screen. Record installation time in field book.
- 5.5 Let well stand undisturbed overnight after installation of downhole equipment, if possible.
- 5.6 Start pump at the lowest possible flow rate and adjust the pumping rate to approximately 100 mL/min. (Refer to pump SOP or manufacturers instructions for pump setup and operation). Record pump start time in field book. Verify the flow rate with a graduated cylinder (or equivalent) by collecting the water from the discharge line for one minute. Record results in field book. Manage the collected water according to project work plans.
- 5.7 Monitor water level to verify that little or no drawdown is occurring in the well. If desired, the flow rate may be increased to up to 300 mL/min in more permeable formations as long as no drawdown is occurring in the well. Record measurements and flow rates in field book. If required, monitor the turbidity using a flow-through cell. If turbidity increases with increasing flow rate, reduce flow rate to minimize turbidity.
- 5.8 Low flow purge two pump and transfer tubing volumes of water at a flow rate of approximately 100 mL/min. A volume is composed of the tubing and equipment volumes, not the volume of the well. Determine pH, temperature, specific conductance, oxidation reduction potential, turbidity and dissolved oxygen values, which should reach stable values prior the collection of the sample. Record purge volume target and actual values in field book. Manage purge water according to project work plans.
- 5.9 Obtain field parameter measurements and record as required by project work plans. Stabilization criteria will be as follows.

<u>Parameter</u>	<u>Stabilization Criteria</u>
pH	± 0.1 units
Specific Conductance	± 3% S/cm
Oxidation Reduction Potential	± 10 mV
Turbidity	2-3 readings < 10 NTU
Dissolved Oxygen	± 0.3 mg/L

- 5.10 Remove flow-through cell from discharge tubing prior to sample collection, if being used. Collect sample at low flow rate (100 mL/min) for laboratory analysis directly into the appropriate sample container from pump discharge tubing. Fill the sample bottles in the following order, as applicable:

1. Volatile organic compounds (VOCs).
  2. Semivolatile organic compounds (SVOCs).
  3. Pesticides/PCBs.
  4. Total petroleum hydrocarbons.
  5. Total metals.
  6. Dissolved metals.
  7. Alkalinity, BOD, total suspended solids, total dissolved solids, sulfate, chloride.
  8. Sulfide.
  9. Cyanide.
  10. Phenols.
  11. Nitrate + nitrite, ammonia, TOC, COD, phosphorus.
- 5.11 Fill the VOC vials completely (i.e., no headspace). Fill the vial until a meniscus forms at the bottle opening. Place the cap on the vial and screw it on. Invert the vial and check for air bubbles. If air bubbles are present, remove the cap and add more sample. Replace the cap and re-inspect the vial for bubbles. Repeat if necessary. Label the vial with the appropriate information. If the vial sample label was filled out before the bottle was filled, verify that the information is correct and sign the label.
- 5.12 Fill the remaining bottles to the shoulder. Cap and label the bottles appropriately (including signature).
- 5.13 Filter the sample to be collected for dissolved metals prior to acid preservation.
- 5.14 Duplicate samples are prepared by alternately filling the container for the “investigative sample” for a particular parameter and then filling the container for the “duplicate sample” for that same parameter. Duplicate samples need to be included on the chain-of-custody form. Check the QAPP or ask the project manager what the duplicate sample requirements are for each project.
- 5.15 Trip blanks (VOCs only) are prepared in the laboratory and are shipped from the laboratory with the VOC sample collection vials for each project. The trip blank vials should be inspected for air bubbles upon receipt from the laboratory. The trip blanks are not opened in the field. A trip blank should be present in each shipping cooler containing VOC samples going to the lab. Trip blanks need to be included on the chain-of-custody form.
- 5.16 Matrix spike/matrix spike duplicates (MS/MSDs), when required for the project, are collected in the same manner as a duplicate sample. Check with the laboratory for the volume requirements for each parameter. MS/MSDs need to be included on the chain-of-custody form. Check the QAPP or ask the project manager what the MS/MSD sample requirements are for each project.

- 5.17 Equipment blanks are prepared by running distilled water through the each piece of the sampling equipment that comes into contact with a groundwater sample. To avoid confusion, do not use the term field blank. Equipment blanks needed to be included on the chain-of-custody form. Check the work plan or ask the project manager what the equipment blank requirements are for each project.
- 5.18 For samples that require acid or base preservation, verify that the required pH is achieved by placing a small amount of sample from the sample container in a clean dish (or equivalent) and test the sample with pH paper. Do not place the pH paper in the sample container or cap. Conduct the pH measurement on the VOC vials on approximately 10% of the samples. Fill an extra VOC vial for pH testing, test the contents of the VOC vial, then discard the VOC vial appropriately.
- 5.19 Samples should be placed into a cooler containing ice immediately after collection.
- 5.20 Turn off pump. Remove non-dedicated downhole equipment from well and decontaminate or dispose of properly.
- 5.21 Replace cap on well and protective casing, and lock.
- 5.22 Ship the samples to the laboratory per project requirements following the Chain-of-Custody SOP (T107).

## **6. References**

- 6.1 Kearl, P. M, Korte, N. E., Stites, M., and J. Baker, 1994, Field Comparison of Micropurging vs. Traditional Ground Water Sampling, Groundwater Monitoring Review, Fall 1994, pp. 183-190.
- 6.2 Parker, L.V., 1994, The Effects of Ground Water Sampling Devices on Water Quality: A Literature Review, Groundwater Monitoring Review, Spring 1994, pp. 130-141.
- 6.3 Puls, Robert, W. and Michael J. Barcelona, 1996, Ground Water Issue, Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures, EPA/540/S-95/504, April 1996.

	<p>Standard Operating Procedure</p> <p><b>Soil Sampling for Chemical Analysis of Lead</b></p>	
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## **1. Applicability**

- 1.1 This Standard Operating Procedure (SOP) covers the collection of soil samples for lead analysis in accordance with the appropriate USEPA sampling method.
- 1.2 This SOP does not address health and safety, equipment decontamination, field parameter measurements, sample preservation, chain-of-custody, or laboratory analysis.

## **2. Equipment/Supplies**

- 2.1 Stainless steel knife or spatula
- 2.2 Stainless steel spoon
- 2.3 Stainless steel bowl
- 2.4 Sample containers
- 2.5 Plastic sheeting
- 2.6 Coolers
- 2.7 Ice
- 2.8 Chain-of-Custody form
- 2.9 Field Log Book
- 2.10 Soil Sampling and Decontamination Equipment
- 2.11 Site-Specific Quality Assurance Project Plan (QAPP)

## **3. Procedure**

- 3.1 Soil samples may be obtained using a split-spoon, auger, trowel, scoop, or other appropriate device for the situation. Soil samples for lead may be collected as "grab" or "composite" samples depending on the project needs. The equipment must be cleaned before each use following the Soil Sampling Equipment Decontamination SOP or equivalent.
- 3.2 Prior to placing the soil into the container, remove larger media such as gravel and organic debris.
- 3.3 If the samples will be composite samples, mix the sample portions in a pre-cleaned stainless steel bowl with a pre-cleaned stainless steel spoon.

- 3.4 Place the sample into the sample container and fill it as completely as possible. Properly label and manage the sample following the Chain-of-Custody procedure described in the QAPP.
- 3.5 Duplicate samples are prepared by alternately filling the container for the "investigative sample" for lead analysis and then filling the container for the "duplicate sample" for that same parameter. Duplicate samples need to be included on the Chain-of-Custody form. Check the FSP and QAPP, or ask the project manager what the duplicate sample requirements are for each project.
- 3.6 Matrix spike/matrix spike duplicates (MS/MSDs), when required for the project, are collected in the same manner as a duplicate sample. Check with the laboratory for the volume requirements for each parameter. MS/MSDs need to be included on the Chain-of-Custody form. MS/MSD samples are not often required for soil samples. Check the FSP and QAPP, or ask the project manager to determine if MS/MSDs will be required.
- 3.7 Equipment blanks are prepared by running distilled water over each piece of the sampling equipment after it has been decontaminated. Equipment blanks may be required to be collected for each piece of sampling equipment individually; check the QAPP for further details concerning equipment blank collection. Equipment blanks need to be included on the Chain-of-Custody form.
- 3.10 Samples should be placed into a cooler containing ice immediately after collection.
- 3.11 Ship the samples to the laboratory per project requirements following the Chain-of-Custody procedure.

**Appendix C**

Field Reports and Logs



Pink Copy - Retain and Attach to Field Notes

## Daily Field Log

Project No.: \_\_\_\_\_ Page \_\_\_\_\_ of \_\_\_\_\_

Site Location: \_\_\_\_\_

Prepared By: \_\_\_\_\_

[illegible]

# EQUIPMENT CALIBRATION LOG

PAGE \_\_\_\_ OF \_\_\_\_

EQUIPMENT MANUFACTURER : \_\_\_\_\_

MODEL #:

[illegible]

# LOW FLOW SAMPLING FIELD PARAMETER LOG

PAGE \_\_\_\_ OF \_\_\_\_

WELL : \_\_\_\_\_

PROJ #: \_\_\_\_\_

DATE : \_\_\_\_\_

LOC: \_\_\_\_\_

[illegible]

Soil Boring Log.xls (Boring Log)

[illegible]

Sheet : 2 of

Project Location: \_\_\_\_\_ Weather Conditions: \_\_\_\_\_

[illegible]

---

Boring No.:

# Water Sampling Log

Project \_\_\_\_\_ Project No. \_\_\_\_\_ Page \_\_\_\_ of \_\_\_\_  
 Site Location \_\_\_\_\_ Date \_\_\_\_\_  
 Site/Well No. \_\_\_\_\_ Replicate No. \_\_\_\_\_ Code No. \_\_\_\_\_  
 Weather \_\_\_\_\_ Sampling Time: Begin \_\_\_\_\_ End \_\_\_\_\_

## Evacuation Data

Measuring Point \_\_\_\_\_  
 MP Elevation (ft) \_\_\_\_\_  
 Land Surface Elevation (ft) \_\_\_\_\_  
 Sounded Well Depth (ft bmp) \_\_\_\_\_  
 Depth to Water (ft bmp) \_\_\_\_\_  
 Water-Level Elevation (ft) \_\_\_\_\_  
 Water Column in Well (ft) \_\_\_\_\_  
 Casing Diameter/Type \_\_\_\_\_  
 Gallons in Well \_\_\_\_\_  
 Gallons Pumped/Bailed  
 Prior to Sampling \_\_\_\_\_  
 Sample Pump Intake  
 Setting (ft bmp) \_\_\_\_\_  
 Purge Time begin \_\_\_\_\_ end \_\_\_\_\_  
 Pumping Rate (ml/min) \_\_\_\_\_  
 Evacuation Method \_\_\_\_\_

## Field Parameters

Temperature (°C) \_\_\_\_\_  
 SpC (mS/cm) \_\_\_\_\_  
 CND (mS/cm) \_\_\_\_\_  
 Dissolved Oxygen (%) \_\_\_\_\_  
 Dissolved Oxygen (mg/L) \_\_\_\_\_  
 pH (s.u.) \_\_\_\_\_  
 ORP (mV) \_\_\_\_\_  
 Turbidity (NTU) \_\_\_\_\_  
 Color \_\_\_\_\_  
 Odor \_\_\_\_\_  
 Appearance \_\_\_\_\_  
 Sampling Method \_\_\_\_\_  
 Remarks \_\_\_\_\_

Constituents Sampled	Container Description	Number	Preservative
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Sampling Personnel \_\_\_\_\_

Well Casing Volumes					
Gal./Ft.	0.5" = 0.01	1-¼" = 0.06	2" = 0.16	3" = 0.37	4" = 0.65
	1" = 0.04	1-½" = 0.09	2-½" = 0.26	3-½" = 0.50	6" = 1.47
bmp	Below measuring point	mL	Milliliter	NTU	Nephelometric turbidity units
°C	Degrees Celsius	mS/cm	Millisiemens per centimeter	PVC	Polyvinyl chloride
ft	Feet	msl	Mean sea level	s.u.	Standard units
gpm	Gallons per minute	N/A	Not applicable	umhos/cm	Micromhos per centimeter
mg/L	Milligrams per liter	NR	Not recorded	VOC	Volatile organic compounds

# Well Construction Log (Unconsolidated)

LAND SURFACE \_\_\_\_\_

↑ ft \_\_\_\_\_ Top of casing

↓ ft \_\_\_\_\_ drilled hole \_\_\_\_\_ inch diameter

Well casing \_\_\_\_\_ inch diameter,

☐ Backfill

☐ Grout \_\_\_\_\_

ft\* \_\_\_\_\_

Bentonite ☐ slurry

ft\* ☐ pellets

ft\* \_\_\_\_\_

Well Screen. \_\_\_\_\_ inch diameter

\_\_\_\_\_, \_\_\_\_\_ slot

☐ Gravel Pack

☐ Sand Pack

☐ Formation Collapse

ft\* \_\_\_\_\_

ft\* \_\_\_\_\_

Measuring Point is Top of Well Casing  
Unless Otherwise Noted.  
\* Depth Below Land Surface

Project \_\_\_\_\_ Well \_\_\_\_\_

Town/City \_\_\_\_\_

County \_\_\_\_\_ State \_\_\_\_\_

Permit No. \_\_\_\_\_

Land-Surface Elevation and Datum:

\_\_\_\_\_ feet ☐ Surveyed

☐ Estimated

Installation Date(s) \_\_\_\_\_

Drilling Method \_\_\_\_\_

Drilling Contractor \_\_\_\_\_

Drilling Fluid \_\_\_\_\_

Development Technique(s) and Date(s)

Fluid Loss During Drilling \_\_\_\_\_ gallons

Water Removed During Development \_\_\_\_\_ gallons

Static Depth to Water \_\_\_\_\_ feet below M.P.

Pumping Depth to Water \_\_\_\_\_ feet below M.P.

Pumping Duration \_\_\_\_\_ hours

Yield \_\_\_\_\_ gpm Date \_\_\_\_\_

Specific Capacity \_\_\_\_\_ gpm/ft

Well Purpose \_\_\_\_\_

Remarks \_\_\_\_\_

Prepared by \_\_\_\_\_



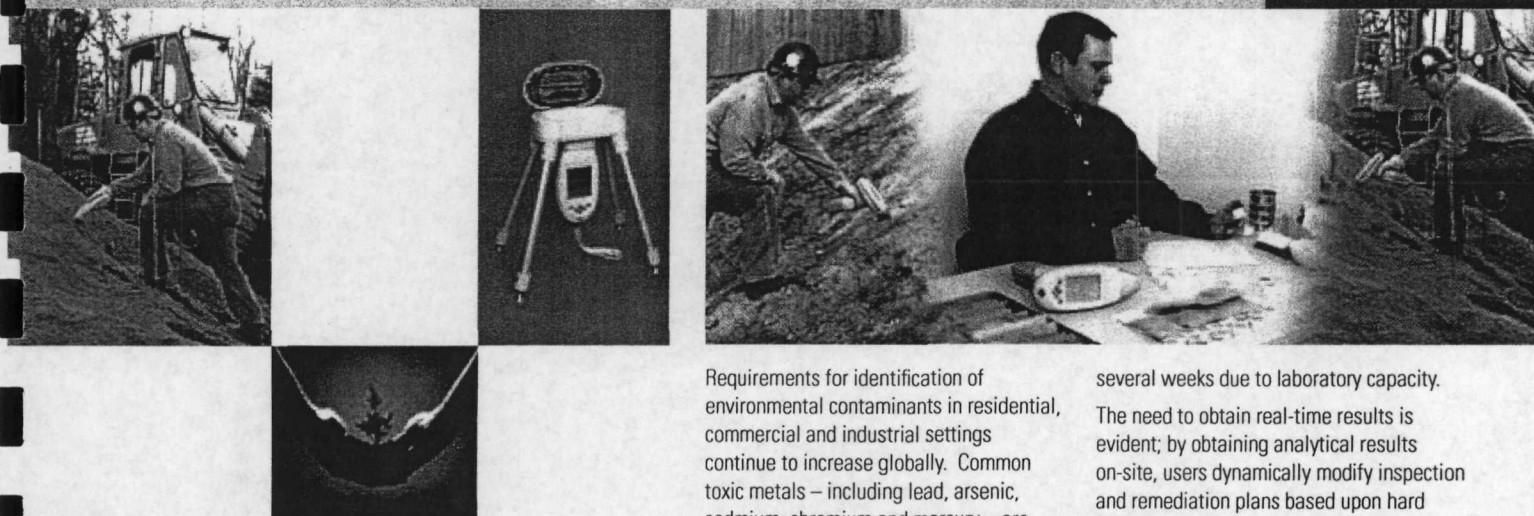
## Appendix D

XRF Specification Sheet

Thermo Scientific NITON XLt, XLp and XLi 700 Series analyzers have become the industry standard for elemental analysis in applications ranging from environmental site characterization and soil analysis to thin film and coatings measurements.

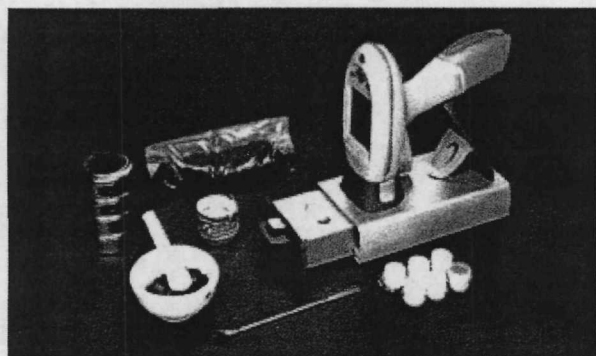
## NITON XLt / XLp / XLi 700

### The Ideal Screening Tool for Environmental Testing



#### Thermo Scientific NITON 700 Series analyzers provide many distinct advantages:

- Very easy to use - even by nontechnical personnel
- Portable GPS integration for real-time contamination mapping
- High-strength, rugged, environmentally sealed housing



Prepared soil sample analysis offers laboratory grade results at a fraction of the cost.

Requirements for identification of environmental contaminants in residential, commercial and industrial settings continue to increase globally. Common toxic metals – including lead, arsenic, cadmium, chromium and mercury – are frequently found in the environment as the result of industrial activity. Whether the unintended consequence of industrial processes or through willful disregard for environmental regulations, the issue cannot be ignored. Analysis must be performed to identify and quantify these contaminants to assess risk and develop remediation plans.

Regulators, consultants and other environmental professionals are faced with the daunting task of collecting and analyzing hundreds or thousands of samples to identify the scope and boundaries of potential contamination, often encompassing large sites. More problematic, sample types are numerous, including soils, sediments, painted surfaces and dust inside structures; ambient air and personal monitoring samples may also be required. Laboratory costs often run into the hundreds of US\$ per sample, with results frequently taking

several weeks due to laboratory capacity.

The need to obtain real-time results is evident; by obtaining analytical results on-site, users dynamically modify inspection and remediation plans based upon hard data, driving efficiencies previously unavailable with more "conventional" approaches. Applications ranging from elevated blood lead (EBL) investigations to site assessment, emergency response to site remediation, and brownfield cleanup to occupational safety and health (OSHA) compliance all directly benefit from the use of field-portable NITON X-ray fluorescence (XRF) analyzers.

NITON Analyzers provide qualitative and lab-quality quantitative results in real-time. They are the worldwide standard for XRF analysis, providing on-site analysis of everything from phosphorus through plutonium with accurate quantification from parts per million (ppm) through percent concentration.

NITON 700 Series analyzers provide 3-sigma precision while maintaining the speed necessary for use as rapid assessment tools. With ease-of-use as their hallmark, they combine light weight with high sensitivity,



Get fast test results in the field with either collected or in-situ sampling.

especially for all 8 RCRA metals, 12 Priority Pollutants and 19 US EPA Target Analytes. A Compton normalization algorithm eliminates the need for time-consuming site-specific calibrations, while maintaining the ability to optimize calibration curves for more sophisticated users.

For the quickest results, NITON 700 Series analyzers are placed directly on the ground, providing in-situ analysis with screening-level results – the ideal way to perform trend analysis or surgically delineate the boundaries of contamination. Placing samples in plastic bags roughly homogenizes the sample for semi-quantitative results, while grinding and sifting the sample provides a more uniform composition, making quantitative analysis possible; these two methods are also known as ex-situ analysis. They comply with US EPA Method 6200 and are the industry standard for site characterization, on-site clearance screening, soil stabilization and remediation quality control. Complete with a full suite of sample preparation and analysis accessories, NITON XRF Analyzers are also available with optional Bluetooth™ wireless capability.

Whether your application requires site screening for potential contamination, emergency response to suspected contamination, or work-site clearance testing, a Thermo Scientific NITON Analyzer provides rapid, high-precision results in a fraction of the time required for traditional laboratory analysis.

*Thermo Scientific NITON 700 Series analyzers are just one of Thermo Fisher's Portable NITON Analyzer solutions which include analysis tools for metal alloy identification, lead-based paint testing, RCRA metals in soil, RoHS and WEEE compliance screening and a host of other analysis needs.*

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## NITON XLt / XLp / XLi 700 Series Specifications

<b>Weight</b>	XLt / XLp: 3.0 lbs (1.4 kg) XLi: 1.7 lbs (0.8 kg)
<b>Dimensions</b>	XLt / XLp: 9.75 x 10.5 x 3.75 inches (248 x 273 x 95 mm) XLi: 11.5 x 3.5 x 3.0 inches (292 x 89 x 76 mm)
<b>Batteries</b>	(2) Rechargeable Quick Swap Li-ion battery packs. 6-14 hour use.
<b>Excitation Source</b>	XLt: Low power (1.0W) X-ray tube with Ag anode target XLp / XLi: One or more of the following sealed radioisotope sources: <sup>241</sup> Am (Infiniton), <sup>55</sup> Fe, <sup>106</sup> Cd
<b>X-ray Detector</b>	High-performance Si-PiN detector; Peltier cooled
<b>Analysis Range</b>	Up to 25 elements (standard) from P to Pb
<b>System Electronics</b>	Hitachi SH-4 CPU ASICS high-speed DSP 4096 channel MCA
<b>Display</b>	Backlit VGA touch screen LCD
<b>Testing Modes</b>	Bulk Sample Mode Thin Sample Mode, including Dust Wipe mode, 37mm Filter Mode User-Defined Thin Sample Mode Lead-Based Paint Mode
<b>Data Storage</b>	Internal ~6000 readings + spectra
<b>Data Entry</b>	Three methods for user data entry: Virtual touch screen keyboard User programmable pull-down lists Integrated barcode reader Optional Portable GPS
<b>Data Transfer</b>	RS-232 serial cable or optional Bluetooth™ wireless connection NDT© PC software utility easily exports data for use in common PC applications and provides encrypted data for safe, secure project documentation.
<b>Standard Accessories</b>	Soil Sampling Kit/ Thin Sample Kit (varies by model & config.) Portable test stand or Inverted stand Check / verification standards Shielded belt holster Locking shielded waterproof carrying case 110/220 VAC charger/adaptor Spare Li-ion battery pack with holster RS-232 PC data transfer cable
<b>Optional Accessories</b>	Benchtop test stand Bluetooth™ wireless communication Wireless Printers and Portable GPS
<b>Security</b>	Password protected user security
<b>Licensing/Registration</b>	Varies by region. Contact Thermo Scientific NITON Analyzers business unit or your local NITON product distributor

NC 7-204  
PS44021\_E0107B

Thermo  
SCIENTIFIC



# NITON® XLt 792Y Series Instruments

## Elemental Limits of Detection in Soils, mg/kg (ppm)

In addition to the offices listed below, Thermo Electron's NITON Group maintains a network of sales and service organizations throughout the world.

NITON Analyzers HQ  
Billerica, MA USA  
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Thermo Electron Corporation's NITON XLt 792Y Series analyzers provide users with the speed and efficiency of X-ray tube excitation, while greatly reducing the regulatory demands typically encountered with an isotope based unit. Various excitation options, including the revolutionary miniature X-ray tube with PERFECT (Programmable Excitation by Regulation of Filters, Energy, Current and Time) technology, are available to meet your particular analytical requirements. The following chart details the sensitivity (LOD) of our XLt 792Y analyzer. These

LOD's are specified for typical soil matrices represented by NIST Standard Reference Materials (SRM). The SRM matrix represents the closest matrix to what would be considered a "real world" soil sample. Detection limits are specified following the EPA protocol of 99.7% confidence level. Individual LOD's improve as a function of the square root of the testing time. All detection limits listed are in parts per million (ppm) unless otherwise stated, and are representative of 60-second tests on each filter.

## XLt 700 Series Analyzer X-ray Tube Excitation

	Sand Matrix	SRM Matrix
Filter 1		
Ba	500	1000
Sb	54	72
Sn	50	70
Ag	30	50
Cd	30	40
Sr	10	10
Rb	4	10
Hg	12	20
Pb	11	18
Se	6	10
As	9	19
Zn	24	48
Cu	50	80
Ni	80	160
Co	150	500
Fe	120	500
Mn	90	300
Filter 2*		
Cr	60	100
V	65	175
Ti	100	200
Sc	45	200
Ca	250	400
K	300	500
Cl	1.30%	1.50%
S	1.30%	1.50%
P	2.20%	2.50%

All values are in ppm (mg/kg) unless otherwise noted. Other elements may be added on request; please contact a NITON agent for technical consultation.

\*Detection of Cr does not necessitate a second filter; however LOD's are optimized using a multi-filter 792Y.

XRF limits of detection (LOD's) are dependent on the following factors:

- Testing time
- Soil matrix
- Level of statistical confidence
- Excitation Source

### Please Note:

Ongoing research and advancements in our XLt Series analyzers will lead to continual improvement in many of the values detailed in this chart.

Contact a Thermo Electron NITON Analyzers office, or your local NITON Analyzers distributor or representative for the latest performance specifications.

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Specifications, terms and pricing are subject to change. Not all products are available in all countries. Please consult your local sales representative for details.

\*An XLt 792Y utilizes PERFECT X-ray tube (Programmable Excitation by Regulating Filters, Energy, Current, and Time) technology.\*

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